GRAY'S ANATOMY

LONGMANS, GREEN AND CO. LTD.
39 PATERNOSTER ROW, LONDON, E.C.4
17 CHITTARANJAN AVENUE, CALCUTTA
NICOL ROAD, BOMBAY
36A MOUNT ROAD, MADRAS

LONGMANS, GREEN AND CO.
114 FIFTH AVENUE, NEW YORK
221 EAST 20TH STREET, CHICAGO
88 TREMONT STREET, BOSTON

LONGMANS, GREEN AND CO.
215 VICTORIA STREET, TORONTO

GRAY'S ANATOMY

DESCRIPTIVE AND APPLIED

TWENTY-SEVENTH EDITION

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WITH 1336 ILLUSTRATIONS
OF WHICH 624 ARE COLOURED
AND 29 ARE X-RAY PLATES

LONGMANS, GREEN AND CO.
LONDON ♦ NEW YORK ♦ TORONTO
1938

BIBLIOGRAPHY

First	*Edition,*	1858	*By HENRY GRAY, F.R.S., F.R.C.S.,* *St. George's Hospital.*
Second	,,	1860	
Third	,,	1863	*By TIMOTHY HOLMES, M.A., F.R.C.S., St. George's Hospital.*
Fourth	,,	1865	
Fifth	,,	1869	
Sixth	,,	1872	
Seventh	,,	1875	
Eighth	,,	1877	
Ninth	,,	1880	
Tenth	,,	1883	*By T. PICKERING PICK, F.R.C.S., St. George's Hospital.*
Eleventh	,,	1887	
Twelfth	,,	1890	
Thirteenth	,,	1893	
Fourteenth	,,	1897	
Fifteenth	,,	1901	*By T. PICKERING PICK, and R. HOWDEN, M.A., M.B., C.M., D.Sc., LL.D., University of Durham.*
Sixteenth	,,	1905	
Seventeenth	,,	1909	*By R. HOWDEN, M.A., M.B., C.M., D.Sc., LL.D., University of Durham.*
Eighteenth	,,	1913	
Nineteenth	,,	1916	
Twentieth	,,	1918	
Twenty-first	,,	1920	
Twenty-second	,,	1923	
Twenty-third	,,	1926	
Twenty-fourth	,,	1930	*By T. B. JOHNSTON, M.D., Guy's Hospital.*
Twenty-fifth	,,	1932	
Twenty-sixth	,,	1935	
Twenty-seventh	,,	1938	

Printed in Great Britain

THE FIRST EDITION OF THIS BOOK

WAS DEDICATED TO

SIR BENJAMIN COLLINS BRODIE, BART.,

F.R.S., D.C.L.,

IN ADMIRATION OF HIS GREAT TALENTS AND IN REMEMBRANCE OF MANY ACTS OF KINDNESS SHOWN TO THE ORIGINAL AUTHOR OF THE BOOK FROM AN EARLY PERIOD OF HIS PROFESSIONAL CAREER.

PREFACE

TO

THE TWENTY-SEVENTH EDITION

In this Edition the section of Arthrology and the section dealing with the Lymphatic System have been rewritten almost in their entirety. Our knowledge of the mechanism of Joints in the living subject has been greatly extended by the progress of Orthopaedic Surgery and the scientific investigation of the *rationale* of Manipulative Surgery, and in rewriting the description of the movements of the various joints I have incorporated much of the modern teaching of Orthopaedics in this respect. With the advice and help of Mr. T. T. Stamm, F.R.C.S., Assistant Orthopaedic Surgeon to Guy's Hospital, to whom I am very specially indebted, much new matter has been added, for, in addition to the movements which can be performed actively, those movements which can be produced only passively or when resistance is encountered to active movements are described, for the first time—so far as I am aware—in a text-book of Human Anatomy. For want of a better name I have called them 'accessory movements', since the term in common use—'passive movements'—logically used, is applicable to all movements which can be carried out passively and therefore is too comprehensive.

The rewriting and rearrangement of the Lymphatic System has been undertaken, almost entirely, by my colleague, Dr. J. Whillis, who has endeavoured to help the student by dealing with the subject on the basis of areas of lymphatic drainage. He has also assisted me throughout the whole work of revision and has earned my most grateful thanks.

In addition, many parts of the other sections have been rewritten and the whole work has been carefully revised. The description now given of the connexions of the thalamus and the new description of the nuclei of the hypothalamus have been based to a large extent on the work of Professor W. E. Le Gros Clark, and I gratefully acknowledge the valuable help I have received both from him personally and from his writings. Many other friends have helped me by criticism and suggestion and, as in previous editions, I am especially indebted to Dr. E. B. Jamieson, and also to Professor D. M. Blair, Professor R. D. Lockhart and Dr. A. J. E. Cave.

The inclusion of a number of X-ray photographs is an innovation which some may regard as overdue, but it must be remembered that in the past an X-ray photograph often proved more confusing than informative to the medical student in the preclinical period. Recently, however, most Departments of Human Anatomy have been equipped with their own X-ray plants, and the student now has the opportunity, in the preclinical period, of acquainting

himself with the appearances shown by the X-rays, so that the inclusion of a limited number of plates is fully justified. All those included are the work of Dr. H. M. Worth, Surgical Radiologist to Guy's Hospital, and I am exceedingly grateful to him for all the care and trouble which he devoted to their preparation and selection.

Many of the older figures have been discarded, and nearly 100 new figures have been introduced in their place, including, in the Myology section, twenty in which the muscles are shown in colour. For many of the new figures I am indebted to Mr. A. K. Maxwell, whose beautiful drawings are so characteristic of his skilful draughtsmanship that they will be identified readily; others are the work of Miss P. A. Larivière, to whom I owe my grateful thanks for her skill, care and willing co-operation. The remainder, eleven in number, have been borrowed from the Myology section of Quain's *Anatomy* (11th edition), and I am greatly indebted to Professor T. H. Bryce for granting me permission to reproduce them. I am also indebted to Professor Bryce for eight of the new figures in the Blood Vascular Section. These were drawn for him some years ago by Mr. A. K. Maxwell, but have not hitherto been published.

The new index is the work of my demonstrator, Mr. H. R. S. Harley, who has earned the grateful thanks of myself and all readers of Gray's *Anatomy* by the care he has taken to maintain the high standard set by his predecessors.

T. B. JOHNSTON.

GUY'S HOSPITAL,
LONDON, 1938.

HENRY GRAY, F.R.S., F.R.C.S.

Henry Gray

As the readers of Gray's Anatomy may be interested to learn something of its original author, Henry Gray, the following information as to his career has been extracted from an article which appeared in the *St. George's Hospital Gazette* of May 21st, 1908.

Gray, whose father was private messenger to George IV. and also to William IV., was born in 1827, but of his childhood and early education nothing is known.

On the 6th of May, 1845, he entered as a perpetual student at St. George's Hospital, London, and he is described by those who knew him as "a most painstaking and methodical worker, and one who learnt his anatomy by the slow but invaluable method of making dissections for himself."

While still a student he secured, in 1848, the triennial prize of the Royal College of Surgeons for an essay entitled, "The origin, connexions and distribution of the nerves to the human eye and its appendages, illustrated by comparative dissections of the eye in other vertebrate animals."

At the early age of twenty-five he was, in 1852, elected a Fellow of the Royal Society, and in the following year he obtained the Astley Cooper prize of three hundred guineas for a dissertation "On the structure and use of the spleen."

He held successively the posts of demonstrator of anatomy, curator of the museum, and lecturer on anatomy at St. George's Hospital, and was in 1861 a candidate for the post of assistant-surgeon. Unfortunately he was struck down by an attack of confluent smallpox, which he contracted while looking after a nephew who was suffering from that disease, and died at the early age of thirty-four. A career of great promise was thus untimely cut short. Writing on June 15th, 1861, Sir Benjamin Brodie said, "His death, just as he was on the point of obtaining the reward of his labours . . . is a great loss to the Hospital and School."

In 1858 Gray published the first edition of his *Anatomy* which covered 750 pages and contained 363 figures. He had the good fortune to secure the help of his friend, Dr. H. Vandyke Carter, a skilled draughtsman and formerly a demonstrator of anatomy at St. George's Hospital. Carter made the drawings from which the engravings were executed, and the success of the book was, in the first instance, undoubtedly due in no small measure to the excellence of its illustrations. A second edition was prepared by Gray and published in 1860.

The portrait here given of Gray is a reproduction of one which appeared in the *St. George's Hospital Gazette* of May 21st, 1908, where the original is described as being "a very faded photograph taken by Mr. Henry Pollock, second son of the late Lord Chief Baron Sir Frederick Pollock, and one of the earliest members of the photographic society of London."

R. H.

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ARTHROLOGY

MYOLOGY

BLOOD VASCULAR SYSTEM

CORRIGENDA

Page 247, line 14, for '*anterior cranial fossa*' read '*middle cranial fossa.*'

Page 867, line 2, for '*left*' read '*right.*'

Page 867, line 3, for '*right*' read '*left.*'

GLOSSARY

LIST OF ALTERATIONS IN THE B.N.A., APPROVED BY THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND, AND INCLUDED IN THE TEXT

Region or Structure	B.R.* English Form	B.R.* Latin Form	Original B.N.A.
Parts of the Body	Neck	Cervix	Collum
	Limbs	Membra	Extremitates
Regions of Body	Nape of neck	Nucha	
	Nuchal furrow	Sulcus nuchæ	Fovea nuchæ
	Root of neck	Radix cervicis	
	Suprasternal fossa	Fossa suprasternalis	Fossa jugularis
	Infraclavicular fossa	Fossa infraclavicularis	Trigonum deltoideopectorale
	Palm of hand	Palma manus	Vola manus
	Fold of buttock	Sulcus natis	Sulcus glutaeus
OSTEOLOGY			
General Terms			
Typical Vertebra	Pedicle	Pediculus [arcus vertebræ]	Radix arcus vertebræ
	Lamina	Lamina [arcus vertebræ]	
	Neural arch	*Arcus neuralis*	
	Centrum	*Centrum*	
	Neurocentral joint	*Articulatio neurocentralis*	
	Costal facet [on transverse process]	Facies costalis [processus transversi]	Fovea costalis transversalis
Atlas	Facet for odontoid process	Facies processus odontoidei	Fovea dentis
Axis	Odontoid process	Processus odontoideus	Dens
Sacrum	Lateral mass	Massa lateralis	Pars lateralis
	Spinous tubercles	Tubercula spinosa	Crista sacralis media
	Transverse tubercles	Tubercula transversa	Cristae sacrales laterales
	Articular tubercles	Tubercula articularia	Cristae sacrales articulares
Thorax	Inlet of thorax	Aditus thoracis	Apertura thoracis superior
	Outlet of thorax	Exitus thoracis	Apertura thoracis inferior
1st Rib	Groove for subclavian artery	Sulcus arteriæ subclaviæ	Sulcus subclaviæ
2nd Rib	Tubercle for serratus anterior	Tuberculum m. serrati anterioris	Tuberositas costæ II
Sternum	Suprasternal notch	Incisura suprasternalis	Incisura jugularis
Skull (as a whole)	Impressions for [cerebral] gyri	Impressiones gyrorum [cerebri]	Impressiones digitatæ
	Pterygomaxillary fissure	Fissura pterygomaxillaris	
	Greater palatine canal	Canalis palatinus major	Canalis pterygopalatinus
	Bony palate	Palatum osseum	Palatum durum
	Incisive fossa	Fossa incisiva	Foramen incisivum
	Incisive foramina (lateral and median)	Foramina incisiva (lateralia et mediana)	
	Anterior (bony) aperture of nose	Apertura (ossea) nasi anterior	Apertura piriformis
	Posterior (bony) aperture of nose	Apertura (ossea) nasi posterior	Choanæ
	Anterior fontanelle	Fonticulus anterior	Fonticulus frontalis (major)
	Posterior fontanelle	Fonticulus posterior	Fonticulus occipitalis (minor)
	Posterolateral fontanelle	Fonticulus posterolateralis	Fonticulus mastoideus
	Anterolateral fontanelle	Fonticulus anterolateralis	Fonticulus sphenoidalis
Occipital Bone	Condylar part	Pars condylaris	Pars lateralis
	Posterior condylar canal	Canalis condylaris posterior	Canalis condyloideus
	Anterior condylar canal	Canalis condylaris anterior	Canalis hypoglossi
Sphenoid Bone	Sphenoid bone	Os sphenoideum	Os sphenoidale
	Optic groove	Sulcus opticus	Sulcus chiasmatis
	Lesser wing	Ala minor	Ala parva
	Greater wing	Ala major	Ala magna
	Spine of sphenoid	Spina ossis sphenoidei	Spina angularis
	Groove for pharyngotympanic tube	Sulcus tubæ pharyngotympanicæ	Sulcus tubæ auditivæ
	Lateral pterygoid plate	Lamina pterygoidea lateralis	Lamina lateralis processus pterygoidei
	Medial pterygoid plate	Lamina pterygoidea medialis	Lamina medialis processus pterygoidei
	Palatinovaginal canal	Canalis palatinovaginalis	Canalis pharyngeus
Temporal Bone	Sigmoid groove	Sulcus sinus sigmoidei	Sulcus sigmoideus
	Internal auditory meatus	Meatus auditorius internus	Meatus acusticus internus
	Canal for facial nerve	Canalis nervi facialis	Canalis facialis [Fallopii]
	Canal for tensor tympani	Canalis m. tensoris tympani	Semicanalis m. tensoris tympani
	Canal for pharyngotympanic tube	Canalis tubæ pharyngotympanicæ	Semicanalis tubæ auditivæ
	Anterior canaliculus for chorda tympani	Canaliculus anterior chordæ tympani	Canaliculus chordæ tympani

* B.R. = British revision.

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
OSTEOLOGY *(continued)*			
Temporal Bone *(continued)*	Posterior canaliculus for chorda tympani	Canaliculus posterior chordæ tympani	
	Squamotympanic fissure	Fissura squamotympanica	Fissura petrotympanica (Glaseri)
	Petrotympanic fissure	Fissura petrotympanica	
	External auditory meatus	Meatus auditorius externus	Meatus acusticus externus
	Zygomatic process [Zygoma]	Processus zygomaticus [Zygoma]	Processus zygomaticus
	Roots of zygoma	Radices zygomatis	
	Tubercle of root of zygoma	Tuberculum radicis zygomatis	
	Supramastoid crest	Crista supramastoidea	
	Articular fossa	Fossa articularis	Fossa mandibularis
	Articular eminence	Eminentia articularis	Tuberculum articulare
Parietal Bone	Parietal eminence	Eminentia parietalis	Tuber parietale
	Groove for sigmoid sinus	Sulcus sinus sigmoidei	Sulcus transversus
Frontal Bone	Frontal eminence	Eminentia frontalis	Tuber frontale
	Orbital plate	Lamina orbitalis	Pars orbitalis
	Nasal spine	Spina nasalis	Spina frontalis
Ethmoid Bone	Ethmoid bone	Os ethmoideum	Os ethmoidale
	Cribriform plate	Lamina cribriformis	Lamina cribrosa
	Ala (cristæ galli)	Ala cristæ galli	Processus alaris (cristæ galli)
	Ethmoidal sinuses	Sinus ethmoidales	Cellulæ ethmoidales
	Orbital plate	Lamina orbitalis	Lamina papyracea
Lacrimal Bone	Crest of lacrimal bone	Crista ossis lacrimalis	Crista lacrimalis posterior
Maxilla	Posterior surface	Facies posterior	Facies infratemporalis
	Dental foramina	Foramina dentalia	Foramina alveolaria
	Dental canals	Canales dentales	Canales alveolares
	Nasolacrimal groove	Sulcus nasolacrimalis	Sulcus lacrimalis
	Lacrimal crest [of maxilla]	Crista lacrimalis [ossis maxillæ]	Crista lacrimalis anterior
	Alveolar arch	Arcus alveolaris	Limbus alveolaris
Palatine Bone	Perpendicular plate	Lamina perpendicularis	Pars perpendicularis
	Greater palatine groove	Sulcus palatinus major	Sulcus pterygopalatinus
	Lesser palatine canals	Canales palatini minores	Canales palatini
	Horizontal plate	Lamina horizontalis	Pars horizontalis
	Tubercle [of palatine bone]	Tuberculum [ossis palatini]	Processus pyramidalis
Zygomatic Bone	Frontal process	Processus frontalis	Processus frontosphenoidalis
	Marginal tubercle	Tuberculum marginale	(Processus marginalis)
Mandible	Alveolar arch	Arcus alveolaris	Limbus alveolaris
	Genial tubercles	Tubercula geniaca	Spina mentalis
	Sublingual fossa	Fossa sublingualis	Fovea sublingualis
	Submandibular fossa	Fossa submandibularis	(Fovea submaxillaris)
	Head of mandible	Caput mandibulæ	Capitulum (processus condyloidei) mandibulæ
	Neck of mandible	Collum mandibulæ	Collum (processus condyloidei) mandibulæ
Bones of Upper Limb	Shoulder girdle	Cingulum membri superioris	Cingulum extremitatis superioris
Scapula	Crest [of scapular spine]	Crista [spinæ scapulæ]	
	Acromial angle	Angulus acromialis	
	Medial border	Margo medialis	Margo vertebralis
	Lateral border	Margo lateralis	Margo axillaris
	Suprascapular notch	Incisura suprascapularis	Incisura scapulæ
	Superior angle	Angulus superior	Angulus medialis
	Spinoglenoid notch	Incisura spinoglenoidalis	
Clavicle	Impression for costoclavicular ligament	Impressio ligamenti costoclavicularis	Tuberositas costalis
	Conoid tubercle	Tuberculum conoideum	Tuberositas coracoidea
	Trapezoid line	Linea trapezoidea	
Skeleton of Free Upper Limb			
Humerus	Greater tuberosity	Tuberositas major	Tuberculum majus
	Lesser tuberosity	Tuberositas minor	Tuberculum minus
	Bicipital groove	Sulcus musculi bicipitis	Sulcus intertubercularis
	Lateral lip	Labium laterale	Crista tuberculi majoris
	Medial lip	Labium mediale	Crista tuberculi minoris
	Spiral groove	Sulcus spiralis	Sulcus nervi radialis
Radius	Head of radius	Caput radii	Capitulum radii
	Interosseous border	Margo interossea	Crista interossea
Ulna	Trochlear notch	Incisura trochlearis	Incisura semilunaris
	Interosseous border	Margo interossea	Crista interossea
Carpus	Carpal bones	Ossa carpalia	Ossa carpi
	Scaphoid bone	Os scaphoideum	Os naviculare manus
	Tubercle of scaphoid	Tuberculum oss. scaph.	Tuberculum oss. nav. man.
	Trapezium	Os trapezium	Os multangulum majus
	Crest of trapezium	Crista ossis trap.	Tuberculum oss. mult. maj.
	Trapezoid	Os trapezoideum	Os multangulum minus
Phalanges	Proximal phalanx	Phalanx proximalis	Phalanx prima
	Middle phalanx	Phalanx media	Phalanx secunda
	Distal phalanx	Phalanx distalis	Phalanx tertia
	Tuberosity of distal phalanx	Tuberositas phalangis distalis	Tuberositas unguicularis
	Head of phalanx	Caput phalangis	Trochlea phalangis
Bones of Lower Limb	Girdle of lower limb	Cingulum membri inferioris	Cingulum extremitatis inferioris

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
OSTEOLOGY (*continued*)			
Hip Bone	Articular surface	Facies articularis	Facies lunata
Ilium	Intermediate area [of iliac crest]	Area intermedia [cristæ iliacæ]	Linea intermedia [cristæ iliacæ]
	Middle gluteal line	Linea glutæa media	Linea glutæa anterior
Ischium	Ramus of ischium	Ramus ossis ischii	Ramus inferior ossis ischii
	Ischial tuberosity	Tuberositas ischiadica	Tuber ischiadicum
Pubis	Pubic crest	Crista pubica	
	Pectineal line	Linea pectinea	Pecten ossis pubis
	Iliopubic eminence	Eminentia iliopubica	Eminentia iliopectinea
Pelvis	Subpubic angle	Angulus subpubicus	Angulus pubis
	False pelvis	Pelvis spuria	Pelvis major
	True pelvis	Pelvis vera	Pelvis minor
	Arcuate line	Linea arcuata	Linea terminalis
	Inlet of pelvis	Aditus pelvis [veræ]	Apertura [pelvis minoris] superior
	Outlet of pelvis	Exitus pelvis [veræ]	Apertura [pelvis minoris] inferior
Femur	Trochanteric line	Linea trochanterica	Linea intertrochanterica
	Trochanteric crest	Crista trochanterica	Crista intertrochanterica
	Spiral line	Linea spiralis	
	Supracondylar lines	Lineæ supracondylares	
	Intercondylar notch	Incisura intercondylaris	Fossa intercondyloidea
	Popliteal surface	Facies poplitea	Planum popliteum
Tibia	Intercondylar area	Area intercondylaris	Fossa intercondyloidea anterior Fossa intercondyloidea posterior
	Tubercle of tibia	Tuberculum tibiæ	Tuberositas tibiæ
	Soleal line	Linea m. solei	Linea poplitea
Fibula	Styloid process	Processus styloideus fibulæ	Apex capituli fibulæ
	Interosseous border	Margo interossea	Crista interossea
	Anterior border	Margo anterior	Crista anterior
	Posterior border	Margo posterior	Crista lateralis
	Anterior surface	Facies anterior *	Facies medialis
	Posterior surface	Facies posterior †	Facies posterior
	Malleolar fossa	Fossa malleoli lateralis	
Tarsus			
Talus	Upper surface of talus	Facies superior tali	Facies superior [trochleæ tali]
	Medial surface of talus	Facies medialis tali	
	Malleolar facet	Facies articularis malleolaris medialis	Facies malleolaris medialis
	Lateral surface of talus	Facies lateralis tali	
	Malleolar facet	Facies articularis malleolaris lateralis	Facies malleolaris lateralis
	Lateral tubercle	Tuberculum laterale	Processus lateralis tali
	Anterior surface of talus	Facies anterior tali	
	Lower surface of talus	Facies inferior tali	
	Posterior surface of talus	Facies posterior tali	
	Medial tubercle Posterior tubercle	Tuberculum mediale Tuberculum posterius	Processus posterior tali
Calcaneum	Calcaneum	Calcaneum	Calcaneus
	Posterior surface	Facies posterior	Tuber calcanei
	Medial tubercle [of calcaneum]	Tuberculum mediale [calcanei]	Processus medialis tuberis calcanei
	Lateral tubercle [of calcaneum]	Tuberculum laterale [calcanei]	Processus lateralis tuberis calcanei
	Anterior tubercle [of calcaneum]	Tuberculum anterius [calcanei]	
	(Peroneal tubercle)	(Tuberculum tendinum mm. peronæorum)	(Processus trochlearis)
Cuneiform Bones	Medial cuneiform bone	Os cuneiforme mediale	Os cuneiforme primum
	Intermediate cuneiform bone	Os cuneiforme intermedium	Os cuneiforme secundum
	Lateral cuneiform bone	Os cuneiforme laterale	Os cuneiforme tertium
Phalanges	Proximal phalanx	Phalanx proximalis	Phalanx prima
	Middle phalanx	Phalanx media	Phalanx secunda
	Distal phalanx	Phalanx distalis	Phalanx tertia
	Tuberosity of distal phalanx	Tuberositas phalangis distalis	Tuberositas unguicularis
	Head of phalanx	Caput phalangis	Trochlea phalangis
Joints	Arthrology	Arthrologia	Syndesmologia
	Joint	Articulatio	Junctura ossium
	Fibrous joint	Articulatio fibrosa	Synarthrosis
	Denticulate suture	Sutura denticulata	
	Flat suture	Sutura plana	Harmonia
	Limbous suture	Sutura limbosa	
	Wedge and groove suture	Schindylesis	
	Cartilaginous joint	Articulatio cartilaginea	Synchondrosis
	Primary cartilaginous joint	Articulatio cartilaginea primaria	
	Secondary cartilaginous joint	Articulatio cartilaginea secundaria	Amphiarthrosis
	Synovial joint	Articulatio synovialis	Diarthrosis
	Plane joint	Articulatio plana	Arthrodia
	Condyloid joint	Articulatio condyloidea	
	Ball and socket joint	Articulatio cotylica	Enarthrosis

* Between anterior and interosseous borders.

† Between interosseous and posterior borders, and subdivided by the medial crest.

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
JOINTS *(continued)*			
General Terms	Capsular ligament	Ligamentum capsulare	Stratum fibrosum [capsulæ articularis]
	Synovial membrane	Membrana synovialis	Stratum synoviale [capsulæ articularis]
Joints of Skull	Cartilaginous joints of skull	Articulationes cartilagineæ cranii	Synchondroses cranii
	Spheno-occipital joint	Articulatio spheno-occipitalis	Synchondrosis spheno-occipitalis
	Sphenopetrous joint	Articulatio sphenopetrosa	Synchondrosis spheno-petrosa
	Petro-occipital joint	Articulatio petro-occipitalis	Synchondrosis petro-occipitalis
Vertebral Joints	Intervertebral discs	Disci intervertebrales	Fibrocartilagines intervertebrales
	{ Superficial posterior sacro-coccygeal lig.	{ Lig. sacrococcygeum post. superficiale	Ligamentum sacrococcygeum posterius superficiale
	Intercornual ligaments	Ligamenta intercornualia	
	Atlanto-axial joint	Articulatio atlanto-axialis	Articulatio atlanto-epistrophica
	Apical ligament of odontoid process	Lig. apicis processus odontoidei	Lig. apicis dentis
Costo-transverse Joint	Lateral costotransverse ligament	Lig. costotransversarium laterale	Lig. tuberculi costae
	Inferior costotransverse ligament	Lig. costotransversarium inferius	Lig. colli costae
	Superior costotransverse ligament	Lig. costotransversarium superius	Lig. costotransversarium anterius
Sternal Joints	Manubriosternal joint	Articulatio manubriosternalis	Synchondrosis sternalis
	Xiphisternal joint	Articulatio xiphisternalis	
Joints of Upper Limb	Suprascapular ligament	Ligamentum suprascapulare	Lig. transversum scapulæ superius
	Spinoglenoid ligament	Ligamentum spinoglenoidale	Lig. transversum scapulæ inferius
Sterno-clavicular Joint	Anterior sternoclavicular ligament	Ligamentum sternoclaviculare anterius	Ligamentum sternoclaviculare
	Posterior sternoclavicular ligament	Ligamentum sternoclaviculare posterius	
Shoulder Joint	Transverse ligament	Ligamentum transversum	
Elbow Joint	Medial ligament [of elbow]	Ligamentum mediale [articulationis cubiti]	Ligamentum collaterale ulnare
	Lateral ligament [of elbow]	Ligamentum laterale [articulationis cubiti]	Ligmentum collaterale radiale
Wrist Joint	Posterior radiocarpal ligament	Ligamentum radiocarpeum posterius	Ligamentum radio-carpeum dorsale
	Anterior radiocarpal ligament	Ligamentum radiocarpeum anterius	Ligamentum radio-carpeum volare
	Medial ligament [of wrist]	Ligamentum mediale [carpi]	Ligamentum collaterale carpi ulnare
	Lateral ligament [of wrist]	Ligamentum laterale [carpi]	Ligamentum collaterale carpi radiale
Intermeta-carpal Joints	Dorsal metacarpal ligaments	Ligamenta metacarpea dorsalia	Ligamenta basium [oss. metacarp.] dorsalia
	Palmar metacarpal ligaments	Ligamenta metacarpea palmaria	Ligamenta basium [oss. metacarp.] volaria
	Interosseous metacarpal ligaments	Ligamenta metacarpea interossea	Ligamenta basium [oss. metacarp.] interossea
Metacarpo-phalangeal Joints	Palmar lig. [of metacarpo-phalangeal joint]	Ligamentum palmare [articulationis metacarpophalangeæ]	Ligamenta accessoria volaria
	Deep transverse ligaments of palm	Ligamenta palmæ transversa profunda	Ligamenta capitulorum [oss. metacarp.] transversa
Inter-phalangeal Joints	Palmar ligament of inter-phalangeal joint	Ligamentum palmare [artic. interphal.]	
Pelvic Joints	Inferior pubic ligament	Ligamentum pubicum inferius	Ligamentum arcuatum pubis
	Anterior pubic ligament	Ligamentum pubicum anterius	
	Posterior pubic ligament	Ligamentum pubicum posterius	
	Interpubic disc	Discus interpubicus	Lamina fibrocartilaginea interpubica
Joints of Lower Limb			
Hip Joint	Ischiofemoral ligament	Ligamentum ischiofemorale	Ligamentum ischiocapsulare
	Pubofemoral ligament	Ligamentum pubofemorale	Ligamentum pubocapsulare
	Latin form used	Labrum acetabulare	Labrum glenoidale
	Ligament of head of femur	Ligamentum capitis femoris	Ligamentum teres femoris
Knee Joint	Lateral ligament [of knee]	Ligamentum laterale [genu]	Ligamentum collaterale fibulare
	Medial ligament [of knee]	Ligamentum mediale [genu]	Ligamentum collaterale tibiale
	Oblique posterior ligament of knee	Ligamentum genu posterius obliquum	Ligamentum popliteum obliquum
	Arcuate ligament of knee	Ligamentum genu arcuatum	Ligamentum popliteum arcuatum
	Lateral semilunar cartilage	Cartilago semilunaris lateralis	Meniscus lateralis
	Medial semilunar cartilage	Cartilago semilunaris medialis	Meniscus medialis
	Infrapatellar synovial fold	Plica synovialis infrapatellaris	Plica synovialis patellaris

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
JOINTS *(continued)*			
Tibiofibular Joints	Superior tibiofibular joint	Articulatio tibiofibularis superior	Articulatio tibiofibularis
	Inferior tibiofibular joint	Articulatio tibiofibularis inferior	Syndesmosis tibiofibularis
	Interosseous tibiofibular ligament	Ligamentum tibiofibulare interosseum	
	Anterior inferior tibiofibular ligament	Ligamentum tibiofibulare inferius anterius	Ligamentum malleoli lateralis anterius
	Posterior inferior tibiofibular ligament	Ligamentum tibiofibulare inferius posterius	Ligamentum malleoli lateralis posterius
Tarsal Joints	Lateral calcaneonavicular ligament	Ligamentum calcaneonaviculare laterale	Pars calcaneonavicularis [ligamenti bifurcati]
	Medial calcaneocuboid ligament	Ligamentum calcaneocuboideum mediale	Pars calcaneocuboidea [ligamenti bifurcati]
	Short plantar ligament	Ligamentum plantare breve	Ligamentum calcaneocuboideum plantare
Intermetatarsal Joints	Interosseous metatarsal ligaments	Ligamenta metatarsea interossea	Ligamenta basium [oss. metatars.] interossea
	Dorsal metatarsal ligaments	Ligamenta metatarsea dorsalia	Ligamenta basium [oss. metatars.] dorsalia
	Plantar metatarsal ligaments	Ligamenta metatarsea plantaria	Ligamenta basium [oss. metatars.] plantaria
Metatarsophalangeal Joints	Deep transverse ligaments of sole	Ligamenta plantæ transversa profunda	Ligamenta capitulorum [oss. metatars.] transversa
MYOLOGY			
General Terms	Tendinous intersection	Intersectio tendinea	Inscriptio tendinea
	Synovial sheath of tendon	Vagina synovialis tendinis	Vagina mucosa tendinis
	Synovial bursa	Bursa synovialis	Bursa mucosa
	Deep fascia	Fascia profunda	
Muscles of Back	Iliocostocervicalis	Musculus iliocostocervicalis	Musculus iliocostalis
	Iliocostalis	M. iliocostalis	M. iliocostalis lumborum
	Costalis	M. costalis	M. iliocostalis thoracis
	Costocervicalis	M. costocervicalis	M. iliocostalis cervicis
	Longissimus thoracis	M. longissimus thoracis	M. longissimus dorsi
	Spinalis thoracis	M. spinalis thoracis	M. spinalis dorsi
	Semispinalis thoracis	M. semispinalis thoracis	M. semispinalis dorsi
	Lumbar fascia	Fascia lumbalis	Fascio lumbodorsalis
Muscles of Head	*Latin form used*	M. occipitofrontalis	M. epicranius
	Frontal belly	Venter frontalis	M. frontalis
	Occipital belly	Venter occipitalis	M. occipitalis
	Epicranial aponeurosis	Aponeurosis epicranialis	Galea aponeurotica
	Latin form used	M. compressor naris	M. nasalis, pars transversa
	Latin form used	M. dilator naris	Pars alaris
	Latin form used	M. depressor anguli oris	M. triangularis
	Latin form used	M. zygomaticus major	M. zygomaticus
			M. quadratus labii superioris
	Latin form used	M. zygomaticus minor	Caput zygomaticum
	Latin form used	M. levator labii superioris	Caput infra-orbitale
	Latin form used	M. levator labii superioris alaeque nasi	Caput angulare
	Latin form used	M. depressor anguli oris	M. quadratus labii inferioris
	Latin form used	M. levator anguli oris	M. Caninus
	Lateral pterygoid muscle	M. pterygoideus lateralis	M. pterygoideus externus
	Medial pterygoid muscle	M. pterygoideus medialis	M. pterygoideus internus
	Parotid fascia	Fascia parotidea	Fascia parotideomasseterica
Muscles of Neck	*Latin form used*	M. longus cervicis	M. longus colli
	Cervical fascia	Fascia cervicis	Fascia colli
Muscles of Thorax	Anterior intercostal membranes	Membranæ intercostales anteriores	Ligamenta intercostalia externa
	Posterior intercostal membranes	Membranæ intercostales posteriores	Ligamenta intercostalia interna
	Latin form used	M. transversus thoracis	M. transversus thoracis
	Latin form used	M. sternocostalis	
	Latin form used	Mm. intercostales intimi	
	Vertebral part [of diaphragm]	Pars vertebralis [diaphragmatis]	Pars lumbalis [diaphragmatis]
	Crus [right and left]	Crus [dextrum et sinistrum]	Crus mediale Crus intermedium Crus laterale
	Medial arcuate ligament	Ligamentum arcuatum mediale	Arcus lumbocostalis medialis [Halleri]
	Lateral arcuate ligament	Ligamentum arcuatum laterale	Arcus lumbocostalis lateralis [Halleri]
Rectus Abdominis	Tendinous intersections	Intersectiones tendineæ	Inscriptiones tendineæ
	Arcuate line	Linea arcuata	Linea semicircularis [Douglasi]
External Oblique	Pectinate part [of inguinal ligament]	Pars pectinea [ligamenti inguinalis]	Ligamentum lacunare [Gimbernati]
	(Reflected part [of inguinal ligament])	(Pars reflexa [ligamenti inguinalis])	Ligamentum inguinale reflexum
Internal Oblique and Transversus	Pectineal ligament	Ligamentum pectineale	
	Conjoint tendon	Tendo conjunctus	Falx inguinalis aponeurotica
Inguinal Canal	Superficial inguinal ring	Annulus inguinalis superficialis	Annulus inguinalis subcutaneus
	Deep inguinal ring	Annulus inguinalis profundus	Annulus inguinalis abdominalis

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
MYOLOGY (*continued*)			
Muscles of Pelvis	Fascia of pelvic muscles	Fascia musculorum pelvinorum	Fascia pelvis
			Fascia endopelvina
	Visceral fascia	Fascia viscerum pelvinorum	Fascia diaphragmatis pelvis superior
	Tendinous arch	Arcus tendineus	Arcus tendineus fasciæ pelvis
			Fascia diaphragmatis pelvis inferior
	[Fascial] sheath of prostate	Vagina [fascialis] prostatæ	Fascia prostatæ
	Rectovesical septum	Septum rectovesicale	
	Retropubic space	Spatium retropubicum	
	Retropubic pad of fat	Corpus adiposum retropubicum	
Muscles of Perineum	Anococcygeal body	Corpus anococcygeum	Ligamentum anococcygeum
	Bulbospongiosus	M. bulbospongiosus	Musculus bulbocavernosus
	Perineal membrane	Membrana perinealis	Fascia diaphragmatis urogenitalis inferior
	Perineal body	Corpus perineale	
	Pudendal canal [of obturator fascia]	Canalis pudendalis [fasciae obturatoriæ]	
Muscles of Upper Limb	*Latin form used*	(Musculus dorso-epitrochlearis)	
	Clavipectoral fascia	Fascia clavipectoralis	Fascia coracoclavicularis
	Bicipital aponeurosis	Aponeurosis m. bicipitis	Lacertus fibrosus
	Humero-ulnar head [of flex. dig. sublim.]	Caput humero-ulnare [m. flex. dig. sublim.]	Caput humerale [m. flexor digit. sublimis]
	Latin form used	M. extensor digitorum	M. extensor digitorum communis
	Latin form used	M. extensor digiti minimi	M. extensor digiti quinti proprius
	Latin form used	M. extensor indicis	M. extensor indicis proprius
	Oblique head [of adductor pollicis]	Caput obliquum [m. adductoris pollicis]	
	Transverse head [of adductor pollicis]	Caput transversum [m. adductoris pollicis]	
	Latin form used	M. abductor digiti minimi	M. abductor digiti quinti
	Extensor retinaculum	Retinaculum tendinum mm. extensorum	Ligamentum carpi dorsale
	Superficial transverse lig. of palm	Lig. palmæ transversum superficiale	Fasciculi transversi
	Flexor retinaculum	Retinaculum tendinum mm. flexorum	Lig. carpi transversum
	Superficial part	Pars superficialis	Lig. carpi volare
Muscles of Lower Limb	Opening in adductor magnus	Hiatus m. adductoris magni	Hiatus tendineus [adductorius]
	Latin form used	M. abductor digiti minimi	M. abductor digiti quinti
	Latin form used	(M. abductor ossis metatarsi quinti)	
	Latin form used	M. flexor digitorum accessorius	M. quadratus plantæ
	Subsartorial canal	Canalis subsartorialis	Canalis adductorius [Hunteri]
	Saphenous opening [of fascia lata]	Hiatus saphenus [fasciæ latæ]	Fossa ovalis
	Cribriform fascia	Fascia cribriformis	Fascia cribrosa
	Anterior intermuscular septum [of leg]	Septum [cruris] intermusculare anterius	Septum intermusculare anterius [fibulare]
	Posterior intermuscular septum [of leg]	Septum [cruris] intermusculare posterius	Septum intermusculare posterius [fibulare]
	Superior extensor retinaculum	Retinaculum tendinum mm. extensorum superius	Lig. transversum cruris
	Inferior extensor retinaculum	Retinaculum tendinum mm. extensorum inferius	Lig. cruciatum cruris
	Flexor retinaculum	Retinaculum tendinum mm. flexorum	Lig. laciniatum
	Superficial transverse lig. of sole	Lig. plantæ transversum superficiale	
	Fibrous flexor sheaths	Vaginæ fibrosæ digitales tendinum mm. flexorum	
Bursæ and Synovial Sheaths	Synovial bursæ and sheaths	Bursæ et vaginæ synoviales	Bursæ et vaginæ mucosæ
	Bursa of superior oblique muscle of eye	Bursa m. obliqui superioris oculi	Bursa musculi trochlearis
	Bursa of tensor palati muscle	Bursa m. tensoris palati	Bursa m. tensoris veli palatini
	Bursa of tendon of triceps muscle	Bursa tendinis m. tricipitis	Bursa subtendinea olecrani
	Synovial sheath of flexor carpi radialis tendon	Vagina synovialis tendinis m. flex. carp. rad.	Bursa m. flexoris carpi radialis
	Trochanteric bursa of gluteus medius muscle	Bursa trochanterica m. glutæi medii	Bursa trochanterica m. glutæi medii anterior
	Bursa of psoas major tendon	Bursa tendinis m. psoadis majoris	Bursa iliopectinea
	Tibial intertendinous bursa	Bursa intertendinea tibialis	Bursa m. sartorii propria
			Bursa anserina
NEUROLOGY			
Spinal Cord	Spinal cord	Chorda spinalis	Medulla spinalis
	Regions [of spinal cord]	Regiones [chordæ spinalis]	
	Segments [of spinal cord]	Segmenta [chordæ spinalis]	
	White columns of spinal cord	Columnæ albæ chordæ spinalis	Funiculi medullæ spinalis
	Anterior white column	Columna alba anterior	Funiculus anterior
	Lateral white column	Columna alba lateralis	Funiculus lateralis
	Posterior white column	Columna alba posterior	Funiculus posterior

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
NEUROLOGY (*continued*)			
Transverse Sections of Spinal Cord	White commissure	Commissura alba	Commissura anterior alba
	Grey commissure	Commissura grisea	Commissura anterior grisea Commissura posterior
	Grey horns	Cornua grisea	Columnæ griseæ
	Anterior horn	Cornu anterius	Columna anterior
	Lateral horn	Cornu laterale	Columna lateralis
	Posterior horn	Cornu posterius	Columna posterior
	Thoracic nucleus	Nucleus thoracalis	Nucleus dorsalis [Stillingi, Clarkii]
Fasciculi or Tracts In Ant. White Column	Anterior intersegmental tract	Fasciculus intersegmentalis anterior	Fasciculus anterior proprius
In Lat. White Column	Posterior spinocerebellar tract	Fasc. spinocerebellaris posterior	Fasciculus cerebellospinalis
	Anterior spinocerebellar tract	Fasc. spinocerebellaris anterior	Fasciculus anterolateralis superficialis [Gowersi]
	Spinotectal tract	Fasc. spinotectalis	
	Lateral intersegmental tract	Fasc. intersegmentalis lateralis	Fasciculus lateralis proprius
Brain			
Medulla Oblongata	Inferior cerebellar peduncle	Pedunculus cerebellaris inferior	Corpus restiforme
	Latin form used	Fasciculus cuneatus	Funiculus cuneatus
	Latin form used	Fasciculus gracilis	Funiculus gracilis
	Gracile tubercle	Tuberculum gracile	Clava
	Anterior external arcuate fibres	Fibræ arcuatæ externæ anteriores	Fibræ arcuatæ externæ
	Posterior external arcuate fibres	Fibræ arcuatæ externæ posteriores	
Pons	Middle cerebellar peduncle	Pedunculus cerebellaris medius	Brachium pontis
Transverse Sections of Med. Ob. and Pons	Dorsal nucleus of vagus	Nucleus dorsalis vagi	Nucleus alæ cinereæ
	Gracile nucleus	Nucleus gracilis	Nucleus funiculi gracilis
	Cuneate nucleus	Nucleus cuneatus	Nucleus funiculi cuneati
	Olivary nucleus	Nucleus olivaris	Nucleus olivaris inferior
	Sensory decussation	Decussatio sensoria	Decussatio lemniscorum
	Olivocerebellar tract	Fasciculus olivocerebellaris	Fibræ cerebello-olivares
	Ventral and dorsal cochlear nuclei	Nuclei n. cochlearis, ventralis et dorsalis	Nuclei nervi acustici Nuclei n. cochlearis
	Medial vestibular nucleus	Nucleus n. vestibularis medialis	Nuclei n. vestibularis
	Lateral vestibular nucleus	Nucleus n. vestibularis lateralis	
	Inferior vestibular nucleus	Nucleus n. vestibularis inferior	
	Superior vestibular nucleus	Nucleus n. vestibularis superior	
	Motor nucleus of trigeminal nerve	Nucleus motorius n. trigemini	Nuclei motorii n. trigemini
	Superior sensory nucleus of trigeminal nerve	Nucleus sensorius superior n. trigemini	
	Mesencephalic tract of trigeminal nerve	Tractus mesencephalicus n. trigemini	Radix descendens [mesencephalica] n. trigemini
	Dorsal nucleus of corpus trapezoideum	Nucleus dorsalis corporis trapezoidei	Nucleus olivaris superior
	Ventral nucleus of corpus trapezoideum	Nucleus ventralis corporis trapezoidei	
Cerebellum	Cerebellar folia	Folia cerebelli	Gyri cerebelli
	Cerebellar fissures	Fissuræ cerebelli	Sulci cerebelli
	Antero-superior lobe *	Lobus anterior superior *	
	Latin form used	Lobulus culminis	Culmen monticuli
	Latin form used	Fissura prima	
	Postero-inferior lobe *	Lobus posterior inferior *	
	Latin form used	Lobulus clivi	Declivi monticuli
	Latin form used	Lobulus folii	Folium vermis
	Latin form used	Lobulus tuberis	Tuber vermis
	Retrotonsillar fissure	Fissura retrotonsillaris	
	Latin form used	Paraflocculus	
	Superior cerebellar peduncle	Pedunculus cerebellaris superior	Brachium conjunctivum
Sections of Cerebellum	Cortex	Cortex	Substantia corticalis
	White matter	Substantia alba	Corpus medullare
	White laminæ	Laminæ albæ	Laminæ medullares
	Folia	Folia	
Fourth Ventricle	Lateral recess of fourth ventricle	Recessus lateralis ventriculi quarti	Recessus lateralis fossæ rhomboideæ
	Floor of fourth ventricle	Solum ventriculi quarti	Fossa rhomboidea
	Vagal triangle	Trigonum n. vagi	Ala cinerea
	Vestibular area	Area nucleorum n. vestibularis	Area acustica
	Auditory striæ	Striæ auditoriæ	Striæ medullares
	Superior medullary velum	Velum medullare superius	Velum medullare anterius
	Inferior medullary velum [R. and L.]	Velum medullare inferius [dext. et sinist.]	Velum medullare posterius
	Median aperture of fourth ventricle	Apertura mediana ventriculi quarti	(Apertura medialis ventriculi quarti [Foramen Magendii])
Midbrain	Medial sulcus	Sulcus medialis	Sulcus n. oculomotorii
	Superior quadrigeminal body	Corpus quadrigeminum superius	Colliculus superior
	Inferior quadrigeminal body	Corpus quadrigeminum inferius	Colliculus inferior
	Tectum [of midbrain]	Tectum [mesencephali]	Lamina quadrigemina
Sections of Midbrain	Aqueduct of midbrain	Aquæductus mesencephali	Aquæductus cerebri [Sylvii]
	Mesencephalic tract of trigeminal nerve	Tractus mesencephalicus n. trigemini	Radix descendens n. trigemini
	Mesencephalic nucleus of trigeminal nerve	Nucleus mesencephalicus n. trigemini	Nucleus radicis descendentis n. trigemini
	Decussation of sup. cerebellar peduncles	Decussatio pedunculorum cerebellarium superiorum	Decussatio brachii conjunctivi
	Interpeduncular nucleus	Nucleus interpeduncularis	Ganglion interpedunculare

* These terms, though used in the text, have not been approved officially.

REGION OR STRUCTURE	B.R. ENGLISH FORM	B.R. LATIN FORM	ORIGINAL B.N.A.
NEUROLOGY (*continued*)			
CEREBRUM			
THIRD VENTRICLE	*Latin form used*	Connexus interthalamicus	Massa intermedia
HYPOTHALAMUS	Subthalamic nucleus	Nucleus subthalamicus	Nucleus hypothalamicus [corpus Luysi]
	Mamillothalamic tract	Fasciculus mamillothalamicus	Fasciculus thalamomamillaris [Vicq d'Azyr]
	Mamillopeduncular tract	Fasciculus mamillopeduncularis	Fasciculi pedunculomamillares
THALAMENCEPHALON	*Latin form used*	Stria habenularis	Stria medullaris
TELENCEPHALON	*Latin form used*	Archipallium	
	Latin form used	Neopallium	
	Cerebral hemisphere	Hemisphærium cerebri	Hemisphærium
GYRI AND SULCI	Superolateral surface	Facies superolateralis	Facies convexa
	Lateral sulcus	Sulcus lateralis	Fissura cerebri lateralis [Sylvii]
	Precentral gyrus	Gyrus præcentralis	Gyrus centralis anterior
	Posterior part [of inf. frontal gyrus]	Pars posterior [gyri frontalis inf.]	Pars opercularis [gyri frontalis inf.]
	Inferior temporal sulcus	Sulcus temporalis inferior	Sulcus temporalis medius
	Postcentral gyrus	Gyrus postcentralis	Gyrus centralis posterior
	Postcentral sulcus	Sulcus postcentralis	Sulcus interparietalis
	Intraparietal sulcus	Sulcus intraparietalis	
	Anterior part [of inf. par. lobule]	Pars anterior [lobuli parietalis inferioris]	Gyrus supramarginalis
	Middle part [of inf. par. lobule]	Pars media [lobuli parietalis inferioris]	Gyrus angularis
	Orbital operculum	Operculum orbitale	Pars frontalis
	Frontal operculum	Operculum frontale	
	Frontoparietal operculum	Operculum frontoparietale	Pars parietalis
	Temporal operculum	Operculum temporale	Pars temporalis
	Paraterminal gyrus	Gyrus paraterminalis	Gyrus subcallosus [Pedunculus corporis callosi]
	Suprasplenial sulcus	Sulcus suprasplenialis	Sulcus subparietalis
	Calcarine sulcus	Sulcus calcarinus	Fissura calcarina
	Postcalcarine sulcus	Sulcus postcalcarinus	
	Isthmus of gyrus cinguli	Isthmus gyri cinguli	Isthmus gyri fornicati
	Medial occipitotemporal gyrus	Gyrus occipitotemporalis medialis	Gyrus fusiformis
	Lateral occipitotemporal gyrus	Gyrus occipitotemporalis lateralis	Gyrus temporalis inferior
RHINENCEPHALON	Olfactory pyramid	Pyramis olfactoria	Trigonum olfactorium
	Paraterminal gyrus	Gyrus paraterminalis	Gyrus subcallosus [Pedunculus corporis callosi]
	Piriform area	Area piriformis	
	Hippocampal formation	Formatio hippocampalis	
	Latin form used	Indusium griseum (corporis callosi)	
	Latin form used	Pes hippocampi	Digitationes hippocampi
	Dentate gyrus	Gyrus dentatus	Fascia dentata hippocampi
	Anterior column of fornix	Columna fornicis anterior	Columna fornicis
	Posterior column of fornix	Columna fornicis posterior	Crus fornicis
	Latin form used	Septum lucidum	Septum pellucidum
	Amygdaloid nucleus	Nucleus amygdaloideus	Nucleus amygdalæ
	Latin form used	Stria semicircularis	Stria terminalis
SECTIONS OF TELENCEPHALON	*Latin form used*	Cortex	Substantia corticalis
	Association fibres	Fibræ annectantes	Fibræ arcuatæ cerebri
	Itinerant fibres *	Fibræ itinerantes	
	Anterior limb of internal capsule	Crus anterius capsulæ internæ	Pars frontalis capsulæ internæ
	Posterior limb of internal capsule	Crus posterius capsulæ internæ	Pars occipitalis capsulæ internæ
	Lentiform part	Pars lentiformis	
	Retrolentiform part	Pars retrolentiformis	
	Optic radiation	Radiatio optica	Radiatio occipitothalamica [Gratioleti]
	Auditory radiation	Radiatio auditoria	
	Thalamocortical fibres	Fibræ thalamocorticales	
MENINGES	Extradural space	Cavum extradurale	Cavum epidurale
	Arachnoid mater of brain	Arachnoidea mater encephali	Arachnoidea encephali
	Arachnoid villi	Villi arachnoidei	
	Posterior median cervical septum	Septum cervicale medianum posterius	Septum cervicale intermedium
PERIPHERAL NERVES	Cranial nerves	Nervi craniales	Nervi cerebrales
OCULOMOTOR	Motor root of ciliary ganglion	Radix motoria ganglii ciliaris	Radix brevis ganglii ciliaris
TRIGEMINAL	Sensory root	Radix sensoria	Portio major
	Trigeminal ganglion	Ganglion n. trigemini	Ganglion semilunare [Gasseri]
	Motor root	Radix motoria	Portio minor
NASOCILIARY N.	Communicating br. with ciliary ganglion	Ramus communicans cum ganglio ciliare	Radix longa ganglii ciliaris
MAXILLARY N.	Ganglionic branches	Rami communicantes cum ganglio sphenopalatino	Nn. sphenopalatini
	Posterior superior dental nerves	Nn. dentales superiores posteriores	Rami alveolares superiores posteriores

* Hitherto termed *projection fibres*.

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
NEUROLOGY (*continued*)			
Infraorbital N.	Middle superior dental nerve	N. dentalis superior medius	Ramus alveolaris superior medius
	Anterior superior dental nerve	N. dentalis superior anterior	Rami alveolares superiores anteriores
Sphenopalatine Ganglion	Short sphenopalatine nerves	Nn. sphenopalatini breves	Rami nasales posteriores superiores laterales Rami nasales posteriores superiores mediales
	Long sphenopalatine nerve	N. sphenopalatinus longus	N. nasopalatinus [Scarpæ]
	Greater palatine nerve	N. palatinus major	N. Palatinus anterior
	Lesser palatine nerves	Nn. palatini minores	N. palatinus medius N. palatinus posterior
Mandibular N.	Buccal n.	N. buccalis	N. buccinatorius
Inf. Dental N.	Inferior dental n.	N. dentalis inferior	N. alveolaris inferior
Otic Ganglion	N. to tensor palati	N. m. tensoris palati	N. tensoris veli palatini
Submandibular Ganglion	Submandibular ganglion	Ganglion submandibulare	Ganglion submaxillare
	Glandular branches	Rami glandulares	Rami submaxillares
Facial N.	Motor root	Radix motoria	
	Sensory root	Radix sensoria	Nervus intermedius
	Ganglion of facial n.	Ganglion n. facialis	Ganglion geniculi
Eighth Nerve	Auditory n.	N. auditorius	N. acusticus
Ninth Nerve	Inferior ganglion	Ganglion inferius	Ganglion petrosum
Tenth Nerve	Superior ganglion	Ganglion superius	Ganglion jugulare
	Inferior ganglion	Ganglion inferius	Ganglion nodosum
Superior Laryngeal N.	External laryngeal n.	N. laryngeus externus	Ramus externus
	Internal laryngeal n.	N. laryngeus internus	Ramus internus
Recurrent Laryngeal N.	Recurrent laryngeal n.	N. laryngeus recurrens	N. recurrens
	Pharyngeal branches Laryngeal branches	Rami pharyngei Rami laryngei	N. laryngeus inferior Ramus anterior Ramus posterior
Vagus Nerve	Pulmonary branches	Rami pulmonales	Rami bronchiales anteriores Rami bronchiales posteriores
Eleventh Nerve	Cranial root	Radix cranialis	
	Spinal root	Radix spinalis	
	Accessory branch to vagus n.	Ramus accessorius ad n. vagum	Ramus internus
Spinal Nerves	Anterior primary ramus	Ramus primarius anterior	Ramus anterior
	White communicating br. Grey communicating br.	Ramus communicans albus Ramus communicans griseus	Ramus communicans
	Posterior primary ramus	Ramus primarius posterior	Ramus posterior
Cervical Plexus	Anterior cutaneous n. of neck	N. cutaneus cervicis anterior	N. cutaneus colli
	Medial supraclavicular nerves	Nn. supraclaviculares mediales	Nn. supraclaviculares anteriores
	Intermediate supraclavicular nerves	Nn. supraclaviculares intermedii	Nn. supraclaviculares medii
	Lateral supraclavicular nerves	Nn. supraclaviculares laterales	Nn. supraclaviculares posteriores
Brachial Plexus	Roots of plexus	Radices plexus	
	N. to rhomboids	N. mm. rhomboideorum	N. dorsalis scapulæ
	N. to serratus anterior	N. m. serrati anterioris	N. thoracalis longus
	Upper trunk	Truncus superior	
	Middle trunk	Truncus medius	
	Lower trunk	Truncus inferior	
	Lateral pectoral n.	N. pectoralis lateralis	N. thoracalis anterior lateralis
Median Nerve	Lateral root of median n.	Radix lateralis n. mediani	
	Medial root of median n.	Radix medialis n. mediani	
	Anterior interosseous n.	N. interosseus anterior	N. interosseus volaris
Median and Ulnar Nerves	Palmar digital nerves	Nn. digitales palmares	Nn. digitales volares communes Nn. digitales volares proprii
Medial Cord	Medial pectoral nerve	N. pectoralis medialis	N. thoracalis anterior medialis
Ulnar Nerve	Dorsal branch [of ulnar n.]	Ramus dorsalis [n. ulnaris]	Ramus dorsalis manus
Posterior Cord	N. to latissimus dorsi	N. m. latissimi dorsi	N. thoracodorsalis
	Circumflex n.	N. circumflexus	N. axillaris
Radial Nerve *	Posterior interosseous nerve	N. interosseus posterior	Ramus profundus
Lumbar Nerves (Posterior Primary Rami)	Gluteal branches	Rami glutæi	Nn. clunium superiores
Sacral Nerves (Posterior Primary Rami)	Gluteal branches	Rami glutæi	Nn. clunium medii
Lumbar Plexus	Femoral br. [of genitofemoral n.]	Ramus femoralis [n. genitofemoralis]	N. lumboinguinalis
	Genital br. [of genitofemoral n.]	Ramus genitalis [n. genitofemoralis]	N. spermaticus externus
Femoral Nerve	Intermediate cutaneous n. of thigh Medial cutaneous n. of thigh	N. cutaneus femoris intermedius N. cutaneus femoris medialis	Rami cutanei anteriores
Sacral Plexus	Gluteal brs. [of posterior cutaneous n. of thigh]	Rami glutæi [n. cutanei femoris posterioris]	Nn. clunium inferiores

* In the B.N.A. the radial nerve ends in the cubital fossa by dividing into a ramus profundus and a ramus superficialis. In the B.R. the radial nerve gives off the posterior interosseous nerve in the cubital fossa and is then continued down through the forearm to end on the dorsum of the hand.

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
NEUROLOGY (*continued*)			
Sciatic Nerve	Lateral popliteal n.	N. popliteus lateralis	N. peronæus communis
	Communicating br. with sural n.	Ramus communicans cum n. surali	Ramus anastomoticus peronæus
	Musculocutaneous n.	N. musculocutaneus	N. peronæus superficialis
	Medial br.	Ramus medialis	N. cutaneus dorsalis medialis
	Lateral br.	Ramus lateralis	N. cutaneus dorsalis intermedius
	Anterior tibial n.	N. tibialis anterior	N. peronæus profundus
	Digital br.	Ramus digitalis	Nn. digitales dorsales hallucis lateralis et digiti secundi medialis
	Medial popliteal n.	N. popliteus medialis	N. tibialis
	Interosseous br. [of n. to popliteus]	Ramus interosseus [n. m. poplitei]	N. interosseus cruris
	Sural n.	N. suralis	N. cutaneus suræ medialis
	Posterior tibial n.	N. tibialis posterior	
	Plantar digital nerves	Nn. digitales plantares	Nn. digitales plantares communes Nn. digitales plantares proprii
	Autonomic nervous system	Systema nervosum autonomicum	
Sympathetic Trunk	White communicating brs.	Rami communicantes albi	Ramus communicans
	Grey communicating brs.	Rami communicantes grisei	
Lumbar Part	Lumbar part of sympathetic system	Pars lumbalis systematis sympathici	Pars abdominalis systematis sympathici
Parasympathetic	Parasympathetic nervous system	Systema nervosum parasympathicum	
	Cranial part	Pars cranialis	
	Spinal part	Pars spinalis	
	Pelvic splanchnic nerves	N. splanchnici pelvini	
	Parasympathetic ganglia	Ganglia parasympathica	
SPECIAL SENSES	Spaces of iridocorneal angle	Spatia anguli iridocornealis	Spatia anguli iridis [Fontanæ]
	Optic disc	Discus opticus	Papilla n. optici
	Iridocorneal angle	Angulus iridocornealis	Angulus iridis
Eyeball	Lens	Lens	Lens crystallina
	Fascial sheath of eyeball	Vagina fascialis bulbi	Fascia bulbi [Tenoni]
Conjunctiva	Ocular part [of conjunctiva]	Pars ocularis [conjunctivæ]	Tunica conjunctiva bulbi
	Palpebral part [of conjunctiva]	Pars palpebralis [conjunctivæ]	Tunica conjunctiva palpebrarum
Lacrimal Apparatus	Lacrimal gland	Glandula lacrimalis	Glandula lacrimalis superior
	Palpebral process	Processus palpebralis	Glandula lacrimalis inferior
	Ducts of lacrimal gland	Ductus glandulæ lacrimalis	Ductuli excretorii
	Lacrimal canaliculi	Canaliculi lacrimales	Ductus lacrimales
The Ear	Maculæ of membranous labyrinth	Maculæ labyrinthi membranacei	Maculæ acusticæ
	Aqueduct of cochlea	Aquæductus cochleæ	Ductus perilymphaticus
Bony Labyrinth	Semicircular canals	Canales semicirculares	Canales semicirculares ossei
	Internal auditory meatus	Meatus auditorius internus	Meatus acusticus internus
Middle Ear	Middle ear [tympanum]	Auris media [tympanum]	
	Roof of tympanum	Tegmen tympani	Paries tegmentalis
	Floor of tympanum	Solum tympani	Paries jugularis
	Medial wall	Paries medialis	Paries labyrinthica
	Posterior wall	Paries posterior	Paries mastoidea
	Anterior wall	Paries anterior	Paries carotica
	Lateral wall	Paries lateralis	Paries membranacea
	Aditus to tympanic antrum	Aditus ad antrum tympanicum	
	Pyramid [of tympanum]	Pyramis [tympani]	Eminentia pyramidalis
Tympanic Membrane	Fibrous layer	Stratum fibrosum	Stratum radiatum Stratum circulare
	Radial fibres	Fibræ radiatæ	
	Circular fibres	Fibræ circulares	
	Pharyngotympanic tube	Tuba pharyngotympanica	Tuba auditiva [Eustachii]
	External ear	Auris externa	
	External auditory meatus	Meatus auditorius externus	Meatus acusticus externus
Auricle	Scaphoid fossa	Fossa scaphoidea	Scapha
Skin	Horny zone [of epidermis]	Zona cornea [epidermis]	Stratum corneum [epidermis]
	Horny layer	Stratum corneum	
	Clear layer	Stratum lucidum	
	Granular layer	Stratum granulosum	
	Germinative zone [of epidermis]	Zona germinativa [epidermis]	Stratum germinativum [epidermis]
	Prickle-cell layer	Stratum aculeatum	
	Basal-cell layer	Stratum basale	
Subcutaneous Tissue	Subcutaneous fatty tissue	Tela adiposa subcutanea	Panniculus adiposus
Breast	Mammary gland	Glandula mammaria	
	Lobes [of mammary gland]	Lobi [glandulæ mammariæ]	Lobi mammæ
VASCULAR SYSTEM	Blood vascular system	Systema vasorum sanguineorum	Angiologia
General Term	Emissary vein	Vena emissaria	Emissarium
Heart	Left surface	Facies sinistra	
	Anterior interventricular groove	Sulcus interventricularis anterior	Sulcus longitudinalis anterior
	Inferior interventricular groove	Sulcus interventricularis inferior	Sulcus longitudinalis posterior
	Atrioventricular groove	Sulcus atrioventricularis	Sulcus coronarius

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
VASCULAR SYSTEM (*continued*)			
Heart (*continued*)	Auricles of atria	Auriculæ atriorum	Auricula cordis
	Membranous part [of ventricular septum]	Pars membranacea [septi ventriculorum]	Septum membranaceum ventriculorum
	Right atrioventricular [tricuspid] orifice	Orificium [tricuspidatum] atrioventriculare dextrum	Ostium venosum
	Left atrioventricular [mitral] orifice	Orificium [mitrale] atrioventriculare sinistrum	
	Pulmonary orifice	Orificium trunci pulmonalis	Ostium arteriosum
	Aortic orifice	Orificium aortæ	
Right Atrium	*Latin form used*	Annulus ovalis	Limbus fossae ovalis [Vieussenii]
Right Ventricle	Right atrioventricular [tricuspid] valve	Valvula [tricuspidalis] atrioventricularis dextra	Valvula tricuspidalis
	Inferior cusp	Cuspis inferior	Cuspis posterior
	Infundibuloventricular crest	Crista infundibuloventricularis	Crista supraventricularis
	Latin form used	Infundibulum	Conus arteriosus
	Pulmonary valve	Valvula trunci pulmonalis	Valvulæ semilunares a. pulmonalis
	Right cusp	Cuspis dextra	Valvula semilunaris anterior
	Posterior cusp	Cuspis posterior	Valvula semilunaris dextra
	Left cusp	Cuspis sinistra	Valvula semilunaris sinistra
	Nodules of pulmonary valve	Noduli valvulæ trunci pulmonalis	Noduli valvularum semilunarium
	Lunules of pulmonary valve	Lunulae valvulæ trunci pulmonalis	Lunulæ valvularum semilunarium
	Moderator band	Fasciculus moderator	
Left Ventricle	Left atrioventricular [mitral] valve	Valvula [mitralis] atrioventricularis sinistra	Valvula bicuspidalis [mitralis]
	Aortic valve	Valvula aortæ	Valvulæ semilunares aortæ
	Left cusp	Cuspis sinistra	Valvula semilunaris posterior
	Right cusp	Cuspis dextra	Valvula semilunaris dextra
	Anterior cusp	Cuspis anterior	Valvula semilunaris sinistra
Myocardium	*Latin form used*	Neuromyocardium	
	Sinu-atrial node	Nodulus sinu-atrialis	
	Atrioventricular node	Nodulus atrioventricularis	
	Atrioventricular bundle	Fasciculus atrioventricularis	
Pericardium	Fibrous pericardium	Pericardium fibrosum	
	Serous pericardium	Pericardium serosum	
	Parietal layer	Lamina parietalis	
	Visceral layer [Epicardium]	Lamina visceralis [Epicardium]	
	Oblique sinus of pericardium	Sinus obliquus pericardii	
	Fold of left vena cava	Plica venæ cavæ sinistræ	
Arteries	Pulmonary trunk [stem]	Truncus pulmonalis	A. pulmonalis
	Right pulmonary artery	A. pulmonalis dextra	Ramus dexter
	Left pulmonary artery	A. pulmonalis sinistra	Ramus sinister
Coronary Arteries	Interventricular br. [of right coronary a.]	R. interventricularis [a. coronariæ dextræ]	R. descendens posterior [a. coronariæ dextræ]
	Interventricular br. [of left coronary a.]	R. interventricularis [a. coronariæ sinistræ]	R. descendens anterior [a. coronariæ sinistræ]
Common Carotid Artery	Carotid sinus	Sinus carotis	
External Carotid	Facial artery	A. facialis	A. maxillaris externa
Superficial Temporal Artery	Zygomatic br.	R. zygomaticus	A. zygomatico-orbitalis
	Anterior br.	R. anterior	R. frontalis
	Posterior br.	R. posterior	R. parietalis
Maxillary Artery	Maxillary a.	A. maxillaris	A. maxillaris interna
	Inferior dental a.	A. dentalis inferior	A. alveolaris inferior
	Buccal a.	A. buccalis	A. buccinatoria
	Posterior superior dental arteries	Aa. dentales superiores posteriores	A. alveolaris superior posterior
	Anterior superior dental arteries	Aa. dentales superiores anteriores	Aa. alveolares superiores anteriores
Ophthalmic Artery	Supratrochlear a.	A. supratrochlearis	A. frontalis
Anterior Cerebral Artery	Cortical brs.	Rami corticales	
	Central branches	Rami centrales	
Middle Cerebral Artery	Cortical brs.	Rami corticales	
	Central brs.	Rami centrales	
	Striate brs.	Rr. striati	
Internal Carotid Artery	Anterior choroid a.	A. chorioidea anterior	A. chorioidea
Basilar Artery	Internal auditory a.	A. auditoria interna	A. auditiva interna
Posterior Cerebral Artery	Cortical brs.	Rami corticales	
	Central brs.	Rami centrales	
	Posterior choroid a.	A. chorioidea posterior	
Internal Mammary Artery	Anterior intercostal arteries	Aa. intercostales anteriores	Rr. intercostales
Thyro-cervical Trunk	Transverse cervical a.	A. cervicalis transversa	A. transversa colli
	Suprascapular a.	A. suprascapularis	A. transversa scapulæ
Axillary Artery	Acromiothoracic a.	A. acromiothoracalis	A. thoracoacromialis

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
VASCULAR SYSTEM (*continued*)			
Profunda Brachii Artery	Ascending branch	R. ascendens	R. deltoideus
	Anterior descending br.	R. descendens anterior	A. collateralis radialis
	Posterior descending br.	R. descendens posterior	
Ulnar Collateral Artery	Ulnar collateral a.	A. collateralis ulnaris	A. collateralis ulnaris superior
	Supratrochlear a.	A. supratrochlearis	A. collateralis ulnaris inferior
Radial Artery	Deep palmar arch	Arcus palmaris profundus	Arcus volaris profundus
Ulnar Artery	Posterior interosseous a.	A. interossea posterior	A. interossea dorsalis
	Anterior interosseous a.	A. interossea anterior	A interossea volaris
	Superficial palmar arch	A. palmaris superficialis	Arcus volaris superficialis
Descending Thoracic Aorta	Posterior intercostal arteries (III-XI)	Aa. intercostales posteriores (III-XI)	Aa. intercostales
	Subcostal a.	A. subcostalis	
Abdominal Aorta	Phrenic a.	A. phrenica	A. phrenica inferior
	Median sacral a.	A. sacralis mediana	A. sacralis media
Inferior Mesenteric Artery	Superior left colic a.	A. colica sinistra superior	A. colica sinistra
	Inferior left colic arteries	Aa. colicæ sinistræ inferiores	Aa. sigmoideæ
	Superior rectal a.	A. rectalis superior	A. haemorrhoidalis superior
Iliac Arteries Branches	Internal iliac a.	A. iliaca interna	A. hypogastrica
	Artery of vas deferens	A. vasis deferentis	A. deferentialis
	Middle rectal a.	A. rectalis media	A hæmorrhoidalis media
	Inferior rectal a.	A. rectalis inferior	A. hæmorrhoidalis inferior
	Transverse perineal a.	A. perinei transversa	A. perinæi
External Iliac Artery (Branches)	Artery to cremaster	A. m. cremasteris	A. spermatica externa
Medial Circumflex Femoral Artery	Ascending br.	R. ascendens	Ramus profundus
	Transverse br.	R. transversus	
	Descending genicular art.	A. genu descendens	A. genu suprema
Veins	Inferior hemiazygos vein	V. hemiazygos inferior	V. hemiazygos
Azygos Tributaries	Superior hemiazygos vein	V. hemiazygos superior	V. hemiazygos accessoria
	Posterior intercostal veins	Vv. intercostales posteriores	Vv. intercostales
Innominate Veins	First [posterior] intercostal v.	V. intercostalis [posterior] prima	V. intercostalis suprema
	Left superior intercostal vein	V. intercostalis superior sinistra	
Cephalic Vein	Acromiothoracic v.	V. acromiothoracalis	V. thoracoacromialis
External Jugular Vein	Suprascapular v.	V. suprascapularis	V. scapulæ transversa
	Transverse cervical veins	Vv. cervicales transversæ	Vv. transversæ colli
Anterior Facial Vein	Supraorbital veins	Vv. supraorbitales	Vv. frontales
	Deep facial v.	V. facialis profunda	
Posterior Facial Vein	Maxillary v. or vv.	V. [vv.] maxillares	Vv. maxillares internæ
Venous Sinuses	Transverse sinus	Sinus transversus	Sinus transversus
	Sigmoid sinus	Sinus sigmoideus	
Cerebral Veins	Superficial middle cerebral v.	V. cerebri media superficialis	V. cerebri media
	Deep middle cerebral v.	V. cerebri media profunda	
	Thalamostriate v.	V. thalamostriata	V. terminalis
Common Iliac Vein	Median sacral vein	V. sacralis mediana	V. sacralis media
Internal Iliac Vein	Internal iliac v.	V. iliaca interna	V. hypogastrica
	Middle rectal v.	V. rectalis media	V. hæmorrhoidalis media
	Inferior rectal v.	V. rectalis inferior	V. hæmorrhoidalis inferior
	Prostatic venous plexus	Plexus venosus prostaticus	Plexus pudendalis
Femoral Vein	Long saphenous v.	V. saphena longa	V. saphena magna
Popliteal Vein	Short saphenous v.	V. saphena brevis	V. saphena parva
Portal Vein	Left gastric v.	V. gastrica sinistra	V. coronaria ventriculi
	Right gastric v.	V. gastrica dextra	
	Prepyloric v.	V. præpylorica	
Inferior Mesenteric Vein	Superior left colic v.	V. colica sinistra superior	V. colica sinistra
	Inferior left colic vv.	Vv. colicæ sinistræ inferiores	Vv. sigmoideæ
	Superior rectal v.	V. rectalis superior	V. hæmorrhoidalis superior
LYMPHATIC SYSTEM	Mediastinal trunk	Truncus mediastinalis	Truncus bronchomediastinalis dexter
	Mastoid lymph glands	Lymphoglandulæ mastoideæ	Lymphoglandulæ auriculares posteriores
	Submandibular lymph glands	Lymphoglandulæ submandibulares	Lymphoglandulæ submaxillares
	Supratrochlear lymph gland	L. supratrochlearis	Lymphoglandulæ cubitales superficiales
	Tracheobronchial lymph glands	Ll. tracheobronchiales	Lymphoglandulæ tracheales
	Bronchopulmonary lymph glands	Ll. bronchopulmonales	Lymphoglandulæ bronchiales
	Inferior tracheobronchial lymph glands	Ll. tracheobronchiales inferiores	
	Superior tracheobronchial lymph glands	Ll. tracheobronchiales superiores	
	Paratracheal lymph glands	Ll. paratracheales	
	Innominate lymph glands	Ll. innominatæ	Ll. mediastinales anteriores
	Internal mammary lymph glands	Ll. mammariæ internæ	Ll. sternales
	Aortic lymph glands	Ll. aorticæ	Ll. lumbales
	Left gastric lymph glands	Ll. gastricæ sinistræ	Ll. gastricæ superiores
	Right gastro-epiploic lymph glands	Ll. gastro-epiploicæ dextræ	Ll. gastricæ inferiores
	Pyloric lymph glands	Ll. pyloricæ	
	Internal iliac lymph glands	Ll. iliacæ internæ	Ll. hypogastricæ
	Superficial inguinal lymph glands	Ll. inguinales superficiales	Ll. inguinales
			Ll. subinguinales superficiales
	Deep inguinal lymph glands	Ll. inguinales profundæ	Ll. subinguinales profundæ

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
DIGESTIVE SYSTEM	Palatoglossal arch	Arcus palatoglossus	Arcus glossopalatinus
Mouth	Oropharyngeal isthmus	Isthmus oropharyngeus	Isthmus faucium
	Sublingual papilla	Papilla sublingualis	Caruncula sublingualis
Salivary Glands	Submandibular gland	Glandula submandibularis	Glandula submaxillaris
	Submandibular duct	Ductus submandibularis	Ductus submaxillaris
Teeth	Root foramen of tooth	Foramen radicis dentis	Foramen apicis dentis
	Dentine [Ivory]	Ebur	Substantia eburnea
	Enamel	Adamas dentis	Substantia adamantina
	Cement	Cæmentum	Substantia ossea
	Wisdom tooth	Dens sapientiæ	Dens serotinus
Tongue	Folia linguæ	Folia linguæ	Papillæ foliatæ
	Palatoglossus	M. palatoglossus	M. glossopalatinus
Palate	Levator palati	M. levator palati	M. levator veli palatini
	Tensor palati	M. tensor palati	M. tensor veli palatini
	Palatopharyngeus	M. palatopharyngeus	M. pharyngopalatinus
Pharynx	Glosso-epiglottic fold	Plica glosso-epiglottica	Plica glosso-epiglottica mediana
	Pharyngo-epiglottic fold	Plica pharyngo-epiglottica	Plica glosso-epiglottica lateralis
	Tonsil	Tonsilla	Tonsilla palatina
	Intratonsillar cleft	Fissura intratonsillaris	Fossa supratonsillaris
	Palatopharyngeal arch	Arcus palatopharyngeus	Arcus pharyngopalatinus
	Pharyngeal isthmus	Isthmus pharyngeus	
	Nasopharyngeal tonsil	Tonsilla nasopharyngea	Tonsilla pharyngea
	Piriform fossa	Fossa piriformis	Recessus piriformis
	Pterygomandibular ligament	Ligamentum pterygomandibulare	Raphe pterygomandibulare
Alimentary Canal	Alimentary canal	Canalis alimentarius	Tuba digestoria
Stomach	Cardiac orifice	Orificium cardiacum	
	Cardiac notch	Incisura cardiaca	
	Angular notch	Incisura angularis	
	Pyloric canal	Canalis pyloricus	
	Pyloric constriction	Strictura pylorica	
	Pyloric orifice	Orificium pyloricum	
Duodenum	First part	Pars prima	Pars superior
	Second part	Pars secunda	Pars descendens
	Third part	Pars tertia	Pars horizontalis [inferior]
	Fourth part	Pars quarta	Pars ascendens
	Ampulla of bile duct	Ampulla ductus choledochi	
Cæcum	Ileocolic orifice	Orificium ileocolicum	
	Ileocolic valve	Valvula ileocolica	Valvula coli
	Vermiform appendix	Appendix vermiformis	Processus vermiformis
Colon	{ Descending colon	{ Colon descendens	{ Colon descendens
	{ Pelvic colon	{ Colon pelvinum	{ Colon sigmoideum
	Sacculations of colon	Sacculi coli	Haustra coli
Rectum	Horizontal folds of rectum	Plicæ horizontales recti	Plicæ transversales recti
Anal Canal	Anal canal	Canalis analis	Pars analis recti
	Anal columns	Columnæ anales	Columnæ rectales
	Anal valves	Valvulæ anales	
	Anal sinuses	Sinus anales	Sinus rectales
Pancreas	Neck of pancreas	Collum pancreatis	
Liver	Lower border	Margo inferior	Margo anterior
	Notch for ligamentum teres	Incisura lig. teretis	Incisura umbilicalis
	Fissure for ligamentum venosum	Fissura ligamenti venosi	Fossa ductus venosi
	Groove for vena cava	Sulcus venæ cavæ	Fossa venæ cavæ
	Fissure for ligamentum teres	Fissura ligamenti teretis	Fossa ligamenti teretis
	Hepatobiliary capsule	Capsula hepatobiliosa	Capsula fibrosa [Glissoni]
	Common hepatic duct	Ductus hepaticus communis	Ductus hepaticus
	Right hepatic duct	Ductus hepaticus dexter	
	Left hepatic duct	Ductus hepaticus sinister	
RESPIRATORY SYSTEM	Respiratory system	Systema respiratorium	Apparatus respiratorius
Nose	Posterior apertures of nose	Aperturæ posteriores nasi	Choanæ
Paranasal Sinuses	Ethmoidal sinuses	Sinus ethmoidales	Cellulæ ethmoidales
External Nose	Movable part of septum	Pars mobilis septi nasi	Septum mobile nasi
Larynx	Thyrohyoid membrane	Membrana thyreohyoidea	Membrana hyothyreoidea
	Cricovocal membrane	Membrana cricovocalis	Conus elasticus
	Cricothyroid ligament	Lig. cricothyreoideum	Lig. cricothyreoideum medium
	Vestibular ligament	Lig. vestibulare	Lig. ventriculare
	Vestibular fold	Plica vestibularis	Plica ventricularis
	Sinus of larynx	Sinus laryngis	Ventriculus laryngis [Morgagnii]
	Saccule of larynx	Sacculus laryngis	Appendix ventriculi laryngis
Lungs	{ Medial surface	{ Facies medialis	Facies mediastinalis
	{ Vertebral part	{ Pars vertebralis	
	{ Mediastinal part	{ Pars mediastinalis	
	Oblique fissure	Fissura obliqua	Fissura interlobaris
	Horizontal fissure [R. lung]	Fissura horizontalis [Pulmonis dextri]	
Pleura	Cervical pleura	Pleura cervicalis	Cupula pleuræ
	Recesses of pleura	Recessus pleuræ	Sinus pleuræ
	Costodiaphragmatic recess	Recessus costodiaphragmaticus	Sinus phrenicocostalis

Region or Structure	B.R. English Form	B.R. Latin Form	Original B.N.A.
RESPIRATORY SYSTEM (*continued*)			
PLEURA (*continued*)	Mediastinum	Mediastinum	Septum mediastinale
	Anterior mediastinum	Mediastinum thoracis anterius	Cavum mediastinale anterius
	Posterior mediastinum	Mediastinum thoracis posterius	Cavum mediastinale posterius
	Middle mediastinum	Mediastinum thoracis medium	
	Superior mediastinum	Mediastinum thoracis superius	
UROGENITAL SYSTEM	Urogenital system	Systema urogenitale	Apparatus urogenitalis
KIDNEY	Renal fat	Adeps renis	Capsula adiposa
URETER	Pelvis of ureter	Pelvis ureteris	Pelvis renalis
URINARY BLADDER	Apex of bladder	Apex vesicæ	Vertex vesicæ
	Neck of bladder	Cervix vesicæ	
URETHRA (MALE)	Spongy part	Pars spongiosa	Pars cavernosa
	Fossa terminalis	Fossa terminalis	Fossa navicularis urethræ [Morgagnii]
PENIS	*Latin form used*	Corpus spongiosum penis	Corpus cavernosum urethræ
	Bulb of penis	Bulbus penis	Bulbus urethræ
EPIDIDYMIS	Canal of epididymis	Canalis epididymidis	Ductus epididymidis
SPERMATIC CORD	Internal spermatic fascia	Fascia spermatica interna	Tunica vaginalis communis [testis et funiculi spermatici]
	Cremaster muscle and fascia	M. cremaster et fascia cremasterica	M. cremaster Fascia cremasterica [Cooperi]
	External spermatic fascia	Fascia spermatica externa	
	Latin form used	Vas deferens	Ductus deferens
SEMINAL VESICLE	Duct of seminal vesicle	Ductus vesiculæ seminalis	Ductus excretorius
PROSTATE	Median lobe	Lobus medianus	Lobus medius
	Sheath of prostate	Vagina [fascialis] prostatæ	Fascia prostatæ
OVARY	Ligament of ovary	Ligamentum ovarii	Lig. ovarii proprium
	Latin form used	Cumulus ovaricus	Cumulus oöphorus
EPOÖPHORON	Tubules of epoöphoron	Tubuli epoöphori	Ductuli transversi
UTERINE TUBE	Pelvic opening of tube	Ostium pelvinum tubæ uterinæ	Ostium abdominale tubæ uterinæ
UTERUS	Internal os of uterus	Os uteri internum	Orificium uteri internum
CERVIX UTERI	Arbor vitæ	Arbor vitæ uteri	Plicæ palmatæ
	External os of uterus	Os uteri externum	Orificium uteri externum
PUDENDUM MULIEBRE	Vestibular fossa	Fossa vestibuli vaginæ	Fossa navicularis [vestibuli vaginæ]
ONTOGENETIC TERMS	*Latin form used*	Decidua parietalis	Decidua vera
	Greek form used	Mesonephros	Corpus Wolffi
	Mesonephric duct	Ductus mesonephricus	Ductus Wolffi
	Paramesonephric duct	Ductus paramesonephricus	Ductus Muelleri
PERITONEUM	Extraperitoneal tissue	Tela extraperitonealis	Tela subserosa
	Greater sac of peritoneum	Saccus major peritonæi	
	Lesser sac of peritoneum	Saccus minor peritonæi	Bursa omentalis
	Opening into lesser sac	Aditus ad saccum minorem	Foramen epiploicum
	Pelvic mesocolon	Mesocolon pelvinum	Mesocolon sigmoideum Mesorectum
	Superior duodenal recess	Recessus duodenalis superior	Recessus duodenojejunalis
	Superior duodenal fold	Plica duodenalis superior	Plica duodenojejunalis
	Recess of pelvic mesocolon	Recessus mesocoli pelvini	Recessus intersigmoideus
	Paracolic grooves	Sulci paracolici	Recessus paracolici
	Infundibulopelvic ligament	Lig. infundibulopelvinum	Lig. suspensorium ovarii
	Sacrogenital fold	Plica sacrogenitalis	Plica rectovesicalis
DUCTLESS GLANDS	Parathyroid glands	Glandulæ parathyreoideæ	
SPLEEN	Medial end	Extremitas medialis	Extremitas superior
	Lateral end	Extremitas lateralis	Extremitas inferior
	Lower border	Margo inferior	Margo posterior
	Upper border	Margo superior	Margo anterior

HUMAN ANATOMY

INTRODUCTION

THE term *human anatomy* comprises a consideration of the various structures which make up the human body. In a restricted sense it deals merely with the parts which form the fully developed individual, and can be demonstrated to the naked eye by various methods of dissection. Regarded from that standpoint, human anatomy may be studied by two methods: (1) the various structures may be considered as individual entities—*systematic anatomy*; or (2) the organs and tissues may be studied as they lie in relationship with one another in the different regions of the body—*topographical* or *regional anatomy*.

It is, however, of great advantage to supplement the facts ascertained by naked-eye dissection by those observed by means of the microscope. In this way two fields of investigation are opened, viz. the study of the minute structure of the various component parts of the body—*histology*; and the study of the human organism in its immature condition, from the fertilisation of the ovum to the birth of the child—*embryology*. The changes through which any organism passes from the fertilisation of the ovum until the fully adult form is reached constitute its *ontogenetic history* or *ontogeny*. *Phylogeny*, on the other hand, comprises the evolutionary history of the group to which the organism belongs. Owing to the difficulty of obtaining material illustrating the earliest stages of human development, recourse must be had to observations on the development of lower but allied forms—*comparative embryology*.

In its broader conception anatomy deals with the factors which have influenced and determined the form, structure and functions of the constituent parts of the body, and this aspect of the subject is termed *morphology*. In this branch much valuable information is obtained from the study of the anatomy of other animals, or *comparative anatomy*.

The direct application of the facts of human anatomy to medicine and surgery constitutes the subject of *applied anatomy*. Finally, the identification of structures underlying the surface of the body may be made the subject of special study, and is termed *surface anatomy*.

In the earlier stages of the development of all vertebrates there are abundant signs of their evolution from a segmented invertebrate type. In their simplest forms the segments are identical with one another, save for their topographical position, and the individual structures contained in each segment are repeated in the other segments. The segments are said to be *serially homologous* with one another, and identical individual structures, repeated from segment to segment, provide further examples of *serial homology*.

When two structures occurring in different animals have similar ontogenetic histories, even though they may show individual differences in other ways, they are said to be *homologous* with each other. Thus, the wing of a bird, the fore-limb of a horse and the upper limb of a man are homologous structures, for, although they differ widely in their structure and functions, they all develop from identical cell-groups in the embryo. Structures which fulfil the same functions in different animals are not necessarily homologous with one another. The gills, which constitute the respiratory apparatus of the

fish, are not homologous with the lungs, which carry out a precisely similar function in man, because they have different ontogenetic histories. Such organs are said to be *analogous*.

SYSTEMATIC ANATOMY.—The various tissues of which the body is composed are built up in different combinations and in varying proportions into organs and structures, which can be arranged in a number of groups or *systems*, according to the functions which they perform.

1. *Osteology*—the bony system or skeleton.
2. *Arthrology*—the articulatory system or joints.
3. *Myology*—the muscular system.

It may be noted that the bony, articulatory and muscular systems, grouped together, constitute the *locomotor apparatus*.

4. *The Blood Vascular System*—comprising the heart, blood-vessels, lymph vessels and lymph glands.
5. *Neurology*—the nervous system. It is convenient to include the organs of the senses in this system.
6. *Splanchnology*—the visceral system. The heart, a thoracic viscus, is included in the blood vascular system, and the remaining viscera are grouped into : (*a*) the *respiratory system* ; (*b*) the *digestive system* ; and (*c*) the *urogenital system*.

For descriptive purposes the body is always assumed to be in the erect posture, with the arms hanging by the side, and the head, the eyes and the palms of the hands directed forwards. The position is an unnatural one, for it entails lateral rotation of the humeri at the shoulder joints. The *median plane* is a vertical plane which passes through the centre of the trunk and divides the body into superficially symmetrical right and left halves. This plane cuts the anterior surface of the body along the *anterior median line*, and the posterior surface, along the *posterior median line*. The median plane will pass approximately through the sagittal suture of the skull, and hence any plane parallel to it is termed a *sagittal plane*. Vertical planes at right angles to the median plane pass through or parallel to the central part of the coronal suture of the skull ; such planes are termed *coronal planes*. Planes drawn at right angles to both sagittal and coronal planes are termed *horizontal planes*.

The terms *anterior* or *ventral* and *posterior* or *dorsal* are employed to describe the front or back of the body or limbs, and the relations of structures within the body to one another. The terms *superior* and *inferior* are used to indicate the relative levels of different structures, but in the study of embryology it is frequently convenient to use the terms *cephalic* and *caudal* to denote relationships to the head and tail ends of the embryo. The terms *proximal* and *distal* are frequently used in the description of the limbs in place of the terms *superior* and *inferior*. To denote relative distances from the median plane, the terms *medial* (nearer to) and *lateral* (further from) are employed.

The terms *superficial* and *deep* are strictly confined to descriptions of the relative depth from the surface of the various structures ; *external* and *internal* are reserved, almost entirely, for describing the walls of cavities or of hollow viscera. For example, a rib possesses an external surface, which is directed away from the thoracic cavity, and an internal surface, which is directed towards the thoracic cavity.

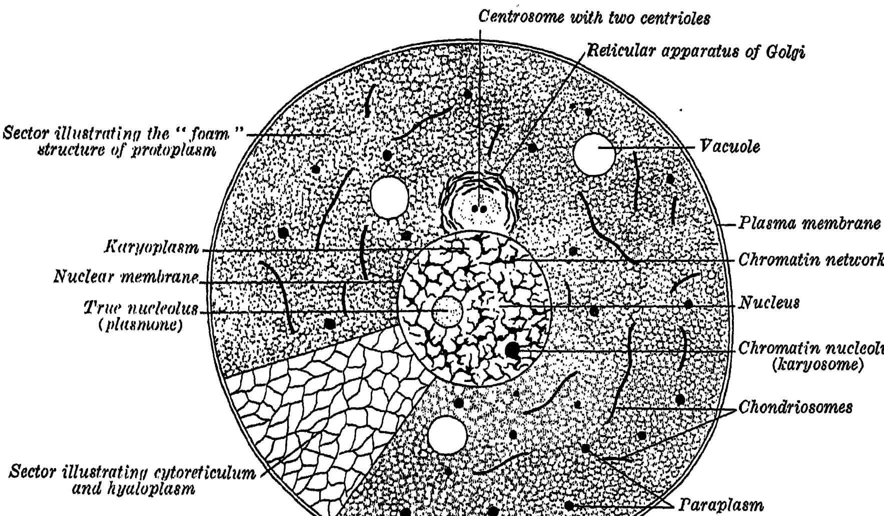
Special terms are restricted for use to certain regions of the body. For example, *palmar* is frequently used instead of *anterior* in the palm of the hand, and *plantar* is employed in descriptions of the sole of the foot and *peroneal* in descriptions of the lateral or fibular aspect of the leg.

HISTOLOGY

THE ANIMAL CELL (fig. 1) *

ALL the tissues and organs of the body originate from the germ-cell (*ovum*) of the female after it has been fertilised by the germ-cell (*spermatozoön*) of the male. The fertilised ovum divides into an enormous number of cells which become variously modified in size, shape and other characteristics according to their positions and functions. All, however, consist of a viscid, unstable, semifluid substance named *protoplasm*. This is a highly complex material of a colloidal nature which consists of water and the following substances in solution or suspension, viz. nitrogenous substances (proteins), fatty bodies (lipoids and phospholipins), starches and sugars (carbohydrates), and inorganic and organic salts. When examined under the high powers of the microscope it may appear

FIG. 1.—A diagram of a cell.



homogeneous, or show some degree of differentiation into fibrils, granules, etc. Within the body of each cell there is usually a small, globular, more solid portion, named the *nucleus*. A cell is therefore frequently defined as "a mass of protoplasm containing a nucleus," but this definition is not altogether satisfactory, because some cells (e.g. red blood-cells of mammals) are non-nucleated, and may carry on their functions for a limited time, while others (e.g. white blood-cells) may be multinucleated.

The **cell-body**. *After fixation with reagents,* such as mercuric chloride, the protoplasm of the body of the cell is seen to consist of a delicate network or *cytoreticulum*, the meshes of which are filled with a more fluid material, named *hyaloplasm*. Granules of fat, pigment or glycogen may be imbedded in the

* Consult *The Cell in Development and Heredity*, by Professor Edmund B. Wilson, 3rd ed. 1925.

cell-protoplasm, and are collectively spoken of as *paraplasm*; vacuoles or spherical spaces filled with fluid may also be present. Most cells are surrounded by a thin wall or *plasma-membrane*, formed by a condensation of the cell-protoplasm.

There are two chief views as to the structure of protoplasm: (*a*) that it consists of a *cytoreticulum* the meshes of which are filled with a more fluid material, named *hyaloplasm*, as described above, and (*b*) that it has an *alveolar* or *foam-like* structure consisting of a viscid interalveolar material having the appearance of a honey-comb, and a more fluid substance consisting of separate alveolar spheres suspended in the interalveolar material; when closely packed the spheres assume a more or less angular form. The supporters of the latter view apply the name *hyaloplasm* to the interalveolar material, and that of *enchylema* to the contents of the spheres.

The **nucleus** is a small, globular structure situated eccentrically within the cell. It contains one or more minute bodies named *nucleoli*, and is readily stained by basic dyes such as carmine or hæmatoxylin. *In fixed and stained preparations* the nucleus exhibits a network (*karyomitome*), the meshes of which are filled with a semifluid substance named *karyoplasm*. The network consists of two constituents, (*a*) a material named *linin*, which stains with acid dyes, and (*b*) a number of more or less discontinuous masses, called *chromatin* because they stain with basic dyes. The karyomitome is condensed around the nucleus to form a distinct *nuclear membrane*.

The **nucleoli** are of two kinds, (*a*) *true nucleoli* or *plasmones*—small, spherical bodies lying in the karyoplasm, and staining readily with acid dyes; one is usually present but sometimes there are two or three; and (*b*) *chromatin nucleoli* or *karyosomes*, which consist of localised thickenings of chromatin.

A **centrosome** is present in most cells. It lies near the nucleus, and has the appearance of a small, spherical mass of clear protoplasm. One or two minute particles, named *centrioles* or *central bodies*, are found within it and play an important part in cell-division. The threads of the protoplasmic reticulum immediately around the centrosome are often radially arranged.

Two other groups of bodies are of general occurrence in animal cells, viz. (*a*) chondriosomes and (*b*) the reticular apparatus of Golgi.

The *chondriosomes*, first described in germ-cells undergoing development into spermatozoa, assume the form of small rods, granules or filaments (*mitochondria*). They are soluble in ether and dilute acetic acid, can be stained by iron-hæmatoxylin and other dyes, and are darkened by osmic acid. When the cell divides they are distributed between the two daughter cells.

The *reticular apparatus of Golgi*, first described in nerve-cells, consists of a network or a group of granules or rods (*Golgi bodies*) in the neighbourhood of the nucleus or of the centrosome. These bodies are blackened by osmic acid, and are best displayed by Golgi's silver-method. During cell-division the reticular apparatus divides into rods or particles which are distributed between the two daughter cells.

Reproduction of cells is effected either by direct or by indirect division.

In *direct division* (*amitosis*) the nucleus becomes constricted in the middle, assuming an hour-glass shape, and then divides into two. This is followed by a cleavage or division of the whole protoplasmic mass of the cell; and thus two daughter cells are formed, each containing a nucleus. The daughter cells are at first smaller than the original mother cell; but they grow, and the process may be repeated in them, so that multiplication may take place rapidly. Direct division is said to occur in leucocytes and bone-cells, and in the epithelial cells lining the urinary bladder.

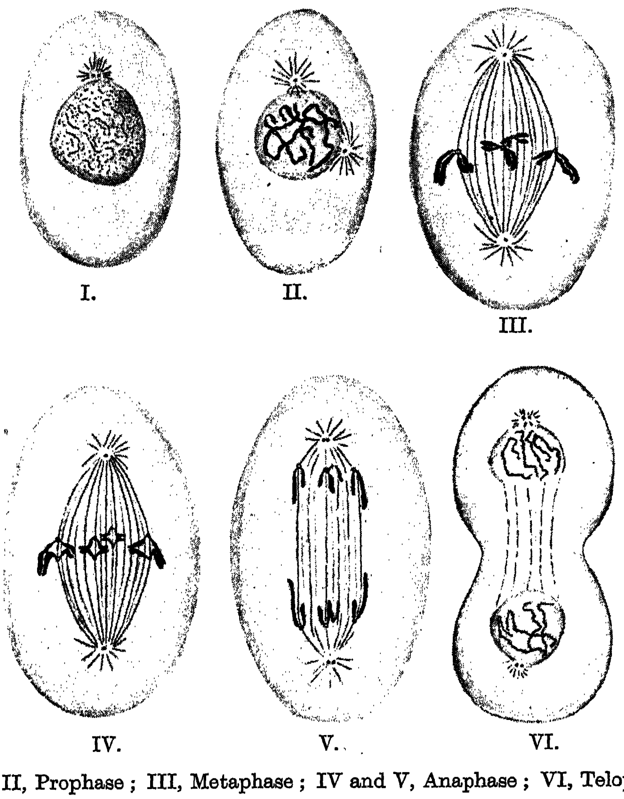
Indirect division or *karyokinesis* (*mitosis*) is the common method of division in the higher animals, and the process is characterised by a series of complex changes in the nucleus, leading to its subdivision; this is followed by cleavage of the cell-protoplasm. Starting with the nucleus in the quiescent or *resting* condition, these changes may be grouped briefly under the four following stages (fig. 2):

1. *Prophase.*—The chromatin network of the nucleus becomes resolved into a number of wavy filaments, termed *chromosomes*, each of which, at the time of its appearance, already consists of two chromatids or daughter chromosomes lying side by side. The number of chromosomes varies widely in different animals but is constant for all the somatic cells in animals of any given species. In man, according to von Winiwarter, the number is forty-eight, of which half

are maternal in origin, and half paternal. Coincident with, or preceding, the definition of the chromosomes, the centrosome divides and the two resulting centrosomes move away from each other—one towards either extremity of the nucleus. As they separate, they are seen to be connected by a spindle of delicate achromatic fibrils, termed the *achromatic spindle*, which elongates proportionately to the separation of the centrosomes. An imaginary line enclosing the spindle midway between its extremities, or *poles*, is named the *equator*.

2. *Metaphase.*—The chromosomes, which have become shorter and irregularly V-shaped, arrange themselves around the equator, each with the apex of the V pointing to the centre of the spindle and linked with one of its fibrils * (fig. 2). This arrangement is termed the equatorial plate, and, when viewed from either pole of the spindle, the plate presents the appearance of an *aster*.

FIG. 2.—A diagram showing the changes which occur in the centrosome and nucleus of a cell in the process of mitotic division.



I and II, Prophase ; III, Metaphase ; IV and V, Anaphase ; VI, Telophase.

3. *Anaphase.*—The two constituent daughter chromosomes of each chromosome separate and travel in opposite directions along the fibrils of the achromatic spindle to group themselves around the centrosomes. Each group contains the same number of daughter chromosomes as there were chromosomes in the equatorial plate, and of these one-half are maternal in origin and one-half paternal.

4. *Telophase.*—The daughter chromosomes lose their identity and the chromatin network, which is characteristic of the resting nucleus, is formed. The nuclear membrane and the nucleolus are differentiated and the cell-protoplasm undergoes constriction around the equator of the achromatic spindle. The constriction deepens and the original cell is gradually divided.

* The changes which the chromosomes undergo in this and in the succeeding stages are exceedingly complicated and a full description would be out of place in this text-book. A detailed account of the present state of our knowledge on the subject will be found in *Recent Advances in Cytology*, by C. D. Darlington, London, 1937.

Homotypical and heterotypical mitosis.—In all somatic cells the process of indirect cell-division conforms to the type described above, and is called *homotypical*. On its completion the nucleus of each daughter cell has as many chromosomes as were present in the nucleus of the mother cell.

During the maturation of a primary oöcyte (p. 46) and also during the subdivision of a primary spermatocyte into spermatids (p. 49) only two consecutive divisions occur, and the nucleus of each of the four resulting cells has only half as many chromosomes as were present in that of the primary oöcyte or spermatocyte. The reduction occurs during the first division, which is named a *heterotypical* or *reduction* division. The second division is homotypical.

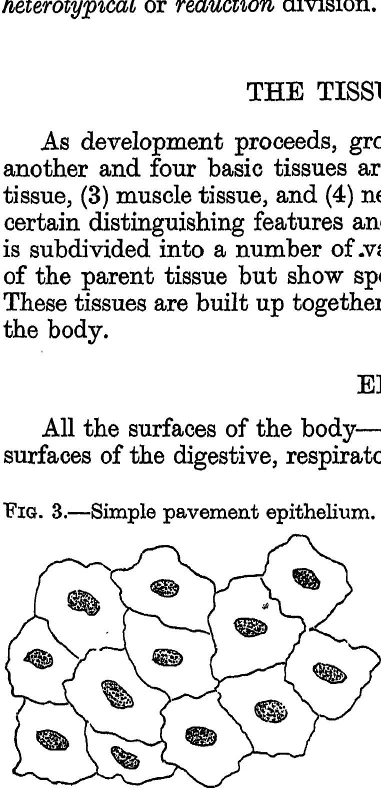
THE TISSUES OF THE BODY

As development proceeds, groups of cells become differentiated from one another and four basic tissues are formed, viz. (1) epithelium, (2) connective tissue, (3) muscle tissue, and (4) nervous tissue. Each of these tissues possesses certain distinguishing features and, with the exception of nervous tissue, each is subdivided into a number of varieties, which retain the essential characters of the parent tissue but show specialisation of one or more of its characters. These tissues are built up together in varying proportions to form the organs of the body.

EPITHELIUM

All the surfaces of the body—the external surface of the skin, the internal surfaces of the digestive, respiratory, and urogenital systems, the closed serous cavities, the inner coats of the vessels, the acini and ducts of all secreting and excreting glands, the ventricles of the brain and the central canal of the spinal cord—are covered with one or more layers of cells, called *epithelium* or *epithelial cells*. These cells serve various purposes. Thus, in the skin, the main purpose served by the epithelium (here called the *epidermis*) is that of protection; as the surface is worn away by the agency of friction new cells are supplied, and thus the true skin and the vessels and nerves which it contains are defended from damage. The epithelial cells of the salivary glands, the pancreas, the gastric glands, and the glands of the small intestine prepare the digestive juices; those covering the intestinal villi are concerned with the absorption of the products of digestion; those lining the serous cavities provide a smooth, moist surface. It should be noted that blood-vessels are absent from all epithelia.

Fig. 3.—Simple pavement epithelium.



The constituent cells of an epithelium are always closely packed together and the intercellular substance is reduced to a minimum. The cells are arranged in one or more layers, usually supported on a basement-membrane, and united together by cement-substance, which is similar in chemical compostion to the matrix or ground-substance of the connective tissues, and has the property of reducing nitrate of silver. Epithelia naturally fall into two groups according to whether there is a single layer of cells (*simple epithelium*), or more than one layer (*stratified epithelium* and *transitional epithelium*).

Figs. 4 and 5.—Columnar epithelial cells, from the small intestine of the cat, stained with picrocarmine. × 600.

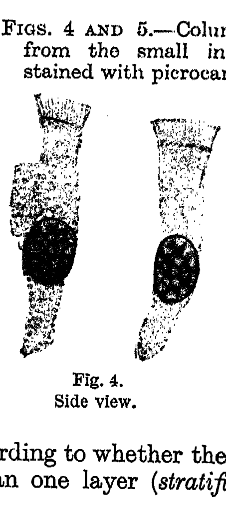


Fig. 4.
Side view.

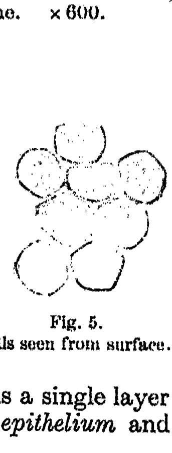
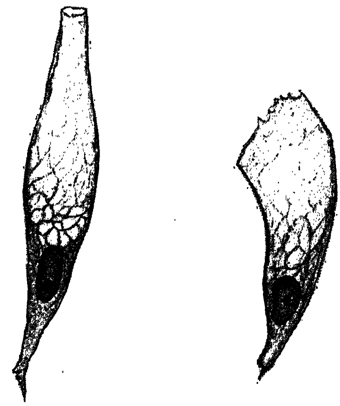


Fig. 5.
Cells seen from surface.

Simple epithelium.—The different varieties of simple epithelium are squamous or pavement, columnar, and ciliated.

Simple squamous or *pavement* epithelium (fig. 3) is composed of flat, nucleated cells of different shapes, usually polygonal, and varying in size. These cells fit together by their edges, like the tiles of a mosaic pavement. The nucleus is generally flattened, but may be spheroidal. The protoplasm of the cell may be fibrillated, the fibrils of adjacent cells being continuous across the intervening cement. This kind of epithelium forms the lining of the alveoli of the lungs. The epithelium which covers the serous membranes, and which lines the heart, blood-vessels and lymphatics, is also of the pavement type. It is, however, derived from the mesoderm and is usually termed *endothelium*, though some authorities make use of the term *mesothelium* with reference to the lining of serous cavities.

Fig. 6.—Goblet cells of a frog. ×500.



Columnar or *cylindrical* epithelium (fig. 4) consists of cylindrical or rod-shaped cells set together so as to form a complete layer, resembling, when viewed in profile, a palisade. The cells have a prismatic figure, owing to mutual pressure, and are set upright on the surface which supports them. The cell-protoplasm is always more or less reticulated; the nucleus is oval in shape and contains an intranuclear network; the centriole is double and lies near the surface of the cell. In the columnar epithelium of the intestinal villi, the free border of each cell shows a refractive cap, which exhibits well-defined vertical striations. Columnar epithelium lines nearly the whole gastro-intestinal tract and its glands, the greater part of the male urethra, the vas deferens, the tubules and ducts of the prostate, the bulbo-urethral glands and the vestibular glands. In a modified form it also covers the ovary.

Goblet- or *chalice-cells* are modified columnar cells. Each appears to be formed by an alteration in shape of a columnar cell (ciliated or otherwise) consequent on the formation in the interior of the cell of granules which consist of a substance called *mucinogen*. This distends the upper part of the cell, and presses the nucleus down towards its deep part, until the cell bursts and the

Fig. 7.—Isolated liver-cells of a rabbit (dissociated). ×500.

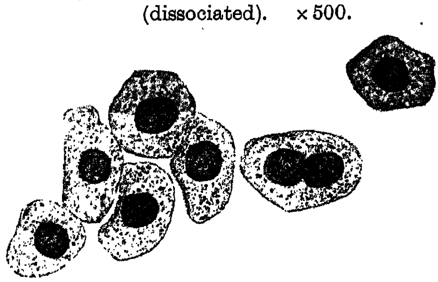
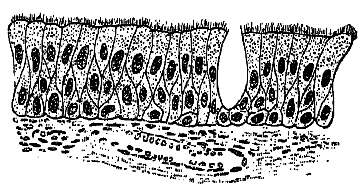


Fig. 8.—Ciliated epithelium from the trachea of a kitten. ×255.



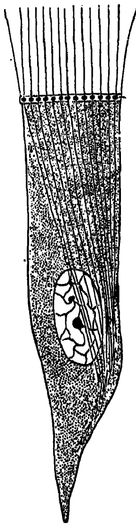
mucus is discharged on to the surface of the mucous membrane (fig. 8), the cell then assuming the shape of an open cup or chalice. A double centriole is found in the mucin-containing part of the goblet-cell. Cells of this kind are especially numerous in the mucous membrane of the stomach, and in the glands of the large intestine; they also occur in the epithelial covering of the villi of the small intestine and in that lining the respiratory tract (fig. 8).

The epithelium of glands is usually columnar, but in some the cells are cubical in shape, in others they are polyhedral. The protoplasm shows a fine reticulum, which gives to the cells a granular appearance (fig. 7). Besides these protoplasmic 'granules,' gland-cells usually contain true granules which

are the products of their own activity. These are in many cases zymogenic in nature, that is, they are, or contain, the precursors of enzymes or ferments.

Ciliated epithelium (fig. 8) is generally columnar in shape. It is distinguished by the presence of minute processes, resembling eyelashes (cilia), standing up from the free surface. The cilia (fig. 9), at their points of attachment to the free border of the cell, possess small nodular enlargements (*basal knobs* of Engelmann); from these knobs fine beaded filaments extend through the cell, and converge to a point near the fixed extremity. The basal knobs or particles have been supposed to be formed by division of the centriole. If the cells are examined during life or immediately on removal from the living body (for which in the human subject the removal of a nasal polypus offers a convenient opportunity) in a weak solution of salt, the cilia will be seen in lashing motion; and if the cells are separated, they will often be seen to be moved about in the field by this ciliary action.

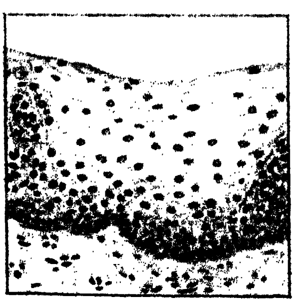
FIG. 9.—A ciliated cell (semidiagrammatic).



Ciliated epithelium lines the respiratory tract from the nose downwards to the smallest ramifications of the bronchial tubes (except in the lower part of the pharynx and on the surfaces of the vocal folds); the tympanic cavity and pharyngotympanic (auditory) tube; the uterine tube and the cavity of the body of the uterus; the efferent ductules of the testis, the lobules of the epididymis and the first part of the vas deferens; the ventricles of the brain and the central canal of the spinal cord.

Stratified epithelium (figs. 10 and 11) consists of several layers of cells. The cells vary greatly in shape; those of the deepest layer are for the most part columnar, and are placed vertically on the basement-membrane; superficial to these the succeeding layers consist of polyhedral cells, which become more and more compressed as they approach the surface; the most superficial cells are found to consist of flattened scales (fig. 10), which overlap one another so as to present an imbricated appearance. The epithelium of the skin is peculiar in that it shows distinct layers. The deep layer consists of columnar and polyhedral cells as in stratified squamous epithelium generally (stratum germinativum). In the next layer, or stratum granulosum, the cells are fusiform in section, and contain granules of a substance called *eleidin*. The third layer, or stratum lucidum, consists of cells in which the eleidin has undergone a transformation into a substance called *keratohyalin*; and the cells of the most superficial layer (stratum corneum) are completely converted into a horny material, known as *keratin* (fig. 11).

FIG. 10.—Stratified squamous epithelium from the œsophagus. (Human). Stained with hæmatoxylin and eosin.



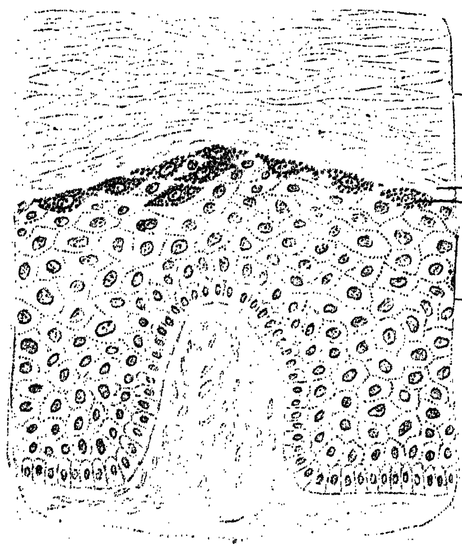
The cells of the deeper layers of stratified squamous epithelium are called *prickle-cells*; they are not closely joined together by cement-substance, but are separated from each other by intercellular channels, between which protoplasmic bridges containing fine fibrils connect the adjacent cells with each other. When a cell is isolated, it appears to be covered over with a number of short spines, in consequence of the bridges being broken through.

Stratified epithelium is found in the skin, in the conjunctiva, on the anterior surface of the cornea, and in the mucous membrane of the mouth, lower part of the pharynx, œsophagus, vagina and part of the cervix uteri.

Transitional epithelium occurs in the ureters and urinary bladder. Here the cells of the most superficial layer are large and flattened, with depressions on their under surfaces to fit on to the rounded ends of the cells of the second

layer, which are pear-shaped, the apices touching the basement-membrane. Between the tapering points of the cells of the second layer is a third variety of cells of smaller size than those of the other two layers (fig. 12). In the distended condition of the bladder the superficial cells are more flattened, and the

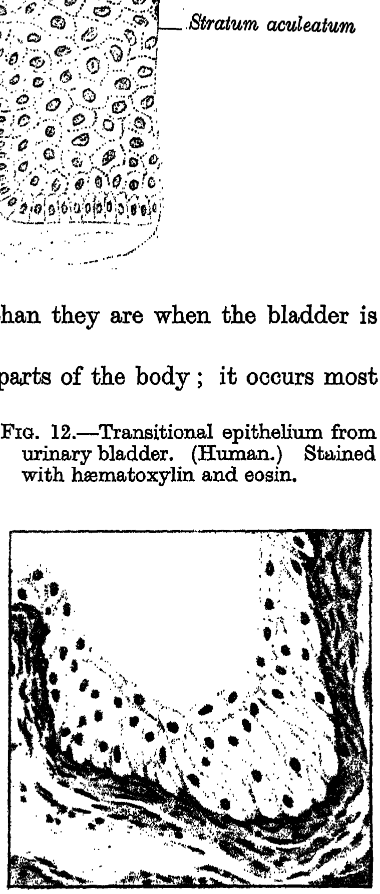
FIG. 11.—A section through the epidermis of the skin of the sole of the foot, stained with hæmatoxylin and van Gieson's stain. ×250.



pear-shaped cells are shorter and broader than they are when the bladder is contracted.

Pigment.—Pigment is found in various parts of the body; it occurs most frequently in epithelial cells and in the cells of connective tissue. Pigmented *epithelial cells* form the external layer of the retina, and are present on the posterior surface of the iris, in the olfactory region of the nose, in the membranous labyrinth of the ear, in the deeper layers of the cuticle, and in the hairs. Pigment is abundantly present in the skin of the coloured races, but in the skin of white races it is well-marked only in the areolæ round the mammary papillæ and in irregular coloured patches.

FIG. 12.—Transitional epithelium from urinary bladder. (Human.) Stained with hæmatoxylin and eosin.



THE CONNECTIVE TISSUES

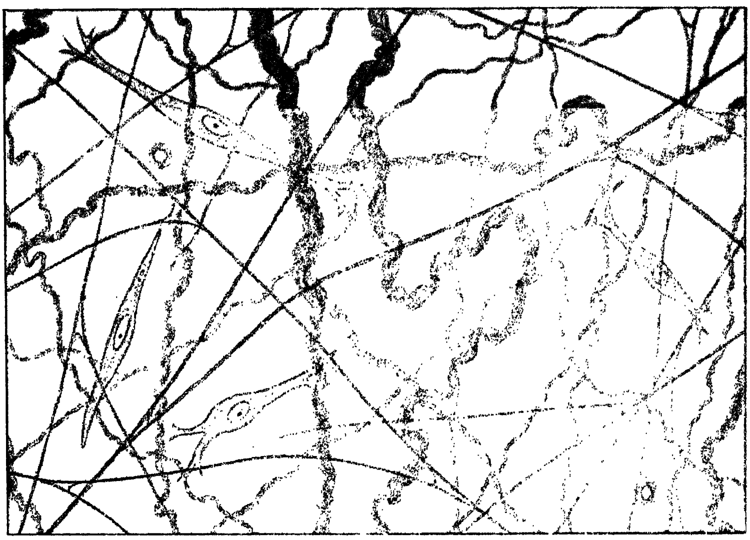
Connective tissues are derived from the mesenchyme, and include a number of tissues which have a passive function, that of binding together or supporting the functionally active structures. They differ considerably from each other in appearance, but present many points of relationship. In contrast to the epithelia the formed matter of the connective tissues lies between and not in the cells.

In a connective tissue the parent cells are separated more or less widely from one another by a homogeneous matrix or ground substance, in which fibres may or may not be present. The most generalised form of connective tissue is termed *areolar tissue* and in it the constituent cells are separated by a semi-fluid matrix in which both white connective tissue and yellow elastic fibres are found

(fig. 13). As contrasted with this generalised form, specialised forms occur in which (*a*) the cells, or (*b*) the matrix, show differentiating characters. In *adipose tissue*, the constituent cells are modified to enable them to contain droplets of oil; in *white fibrous* and *yellow elastic tissue*, it is the fibres which predominate; in *cartilage* and *bone*, the matrix has been rendered solid, whereas in *blood* and *lymph* the cells show special features and the matrix is fluid in character.

Areolar tissue (fig. 13) is so called because, when artificially distended with air or fluid, it exhibits intercommunicating areolæ or spaces. It is extensively distributed and its chief use is to bind parts together, though allowing, in virtue of its extensibility and elasticity, a considerable amount of movement to take place. It occurs as subcutaneous tissue, as the submucous coat in the digestive tract, and as subserous tissue. It is also found between muscles, vessels, and nerves, forming investing sheaths for them, and connecting them with surrounding structures. It is present in the interior of organs, binding together

FIG. 13.—Subcutaneous areolar tissue from a rabbit. Highly magnified.



the lobes and lobules of the compound glands, the various coats of the hollow viscera, and the fibres of muscles and nerves.

When areolar tissue is stretched it is seen to be made up of soft elastic threads, resembling spun silk, and interlacing in all directions. A thin layer, examined under the microscope, shows fibres and cells, imbedded in a homogeneous ground-substance or *matrix*.

The fibres form an irregular meshwork, and are of two kinds—white and yellow. The *white fibres* are exceedingly fine; they are colourless, homogeneous and transparent, and are arranged parallel with each other in bundles which have a wavy course. The individual fibres do not branch, but small bundles of them may leave one large bundle to join another. The *yellow* or *elastic fibres* have well-defined outlines and are usually somewhat larger than the white fibres. They are pale yellow in colour and homogeneous in appearance. They run a comparatively straight course, branch and join up freely with each other. When they are broken across, the ends tend to curl up. They differ from the white fibres also in their staining reactions; they stain a dark red colour with orcein.

The cells of areolar tissue are of four principal kinds: (1) Flattened *lamellar cells*, which may be branched or unbranched. The branched lamellar cells are composed of clear protoplasm, with few granules, and contain oval nuclei; their processes may unite with those of neighbouring cells, so as to form a

syncytium, as in the cornea. Occasionally a cell may be found which shows fibrillation of its protoplasm. Some observers believe such a condition to be a stage in the formation of the white fibres. The unbranched cells are joined edge to edge like the cells of an epithelium ; the flattened cells lining the serous cavities are examples of this variety. (2) *Clasmatocytes* are large irregular cells characterised by the presence of granules or vacuoles in their protoplasm, and containing oval nuclei. (3) *Granule-cells* are ovoid or spheroidal in shape and contain basiphil granules. (4) *Plasma-cells* of Waldeyer are usually spheroidal in shape and distinguished by containing a vacuolated protoplasm ; the vacuoles are filled with fluid, and the protoplasm between them is clear, with occasionally a few scattered basiphil granules.

In addition to these four types of cells, areolar tissue may contain *wandering cells*, i.e. leucocytes which have emigrated from the neighbouring vessels ; in some instances, as in the choroid coat of the eye, cells filled with granules of pigment (*pigment-cells*) are found (p. 13).

FIG. 14.—Areolar tissue of a rabbit, silvered. × 225.
Ground-substance stained, cell-spaces unstained.

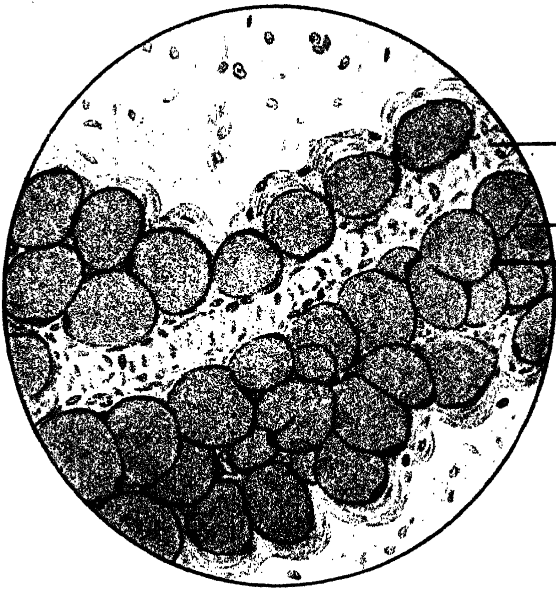
The cells lie in spaces in the ground-substance between the bundles of fibres, and these spaces may be brought into view by treating the tissue with nitrate of silver and exposing it to the light ; this will colour the ground-substance and leave the cell-spaces unstained (fig. 14).

Adipose tissue.—In almost all parts of the body areolar tissue contains a variable quantity of adipose tissue or fat. The principal situations where it is *not* found are the subcutaneous tissue of the eyelids, of the penis and scrotum, and of the labia minora ; within the cavity of the cranium ; and in the lungs, except near their roots. The distribution of adipose tissue is not uniform ; in some parts it is in great abundance, as in the subcutaneous tissue, especially of the abdomen, around the kidneys, and in the mesentery and omentum. Lastly, fat enters largely into the formation of the marrow of bones.

Adipose tissue consists of *fat-cells*, lodged in the meshes of areolar tissue. Fat-cells (fig. 15) vary in size, the average diameter being about 50μ ; each consists of an exceedingly delicate protoplasmic membrane, filled with fatty substance, which is liquid during life, but solidifies after death. They are round or spherical where they are not subjected to pressure ; otherwise they are more or less polygonal. A nucleus is always present under the cell-membrane and can be demonstrated by staining with hæmatoxylin ; in the natural condition

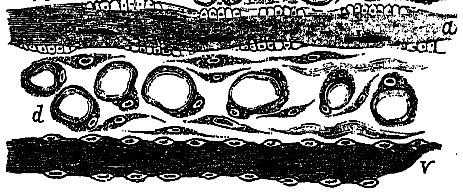
it is so compressed by the contained oily matter as to be scarcely recognisable. The fat-cells are held together mainly by the network of capillary blood-vessels which is distributed to them.

FIG. 15.—Adipose tissue, from the omentum. Stained with Sudan III. and hæmatoxylin. ×350.



Chemically the oily material is composed of olein, palmitin, and stearin, which are glyceryl esters of fatty acids. Sometimes fat-crystals form in the cells after death. By boiling the tissue in ether or strong alcohol, the fat may be extracted from the cells, which are left empty and shrunken.

FIG. 16.—Development of fat. (Klein and Noble Smith)



a. Minute artery. *v.* Minute vein. *c.* Capillary blood-vessels in the course of formation; they are not yet completely hollowed out, there being still left in them protoplasmic septa. *d.* The ground-substance, containing numerous nucleated cells, some of which are more distinctly branched and flattened than others, and appear therefore more spindle-shaped.

Fat first appears in the human embryo about the fourteenth week. The fat-cells are formed by the transformation of connective tissue cells. Small droplets of oil are formed in the protoplasm, and these coalesce to produce a larger drop, which increases until it distends the cell, the remaining protoplasm and the nucleus being displaced towards the periphery (fig. 16).

White fibrous tissue is a true connecting structure which develops in situations where strength is required without rigidity or elasticity. It serves three purposes in the animal economy. In the form of ligaments it binds bones together; in the form of tendons it connects muscles with bones or other structures; it constitutes investing or protecting membranes to various organs. Examples of such membranes are to be found in the fasciæ or sheaths of the muscles, the periosteum, and the perichondrium; the capsules of the various glands; the investing sheaths of the nerves (perineurium) and of various organs, such as the penis and the eye.

In white fibrous tissue, as its name implies, the white fibres (fig. 17) predominate; the matrix is apparent only as a cement-substance, yellow elastic fibres are comparatively few, while the tissue-cells are arranged in a special manner. It presents to the naked eye a silvery white, glistening appearance; it is devoid of elasticity, and has only the very slightest extensibility; it is

FIG. 17.—White fibres. ×350.

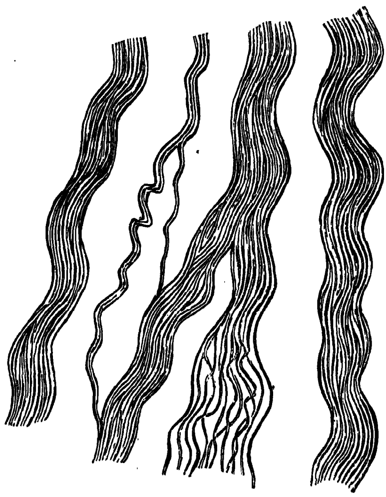
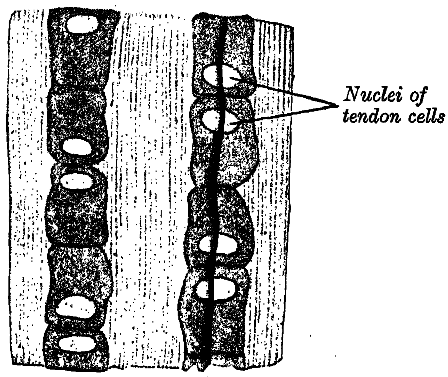
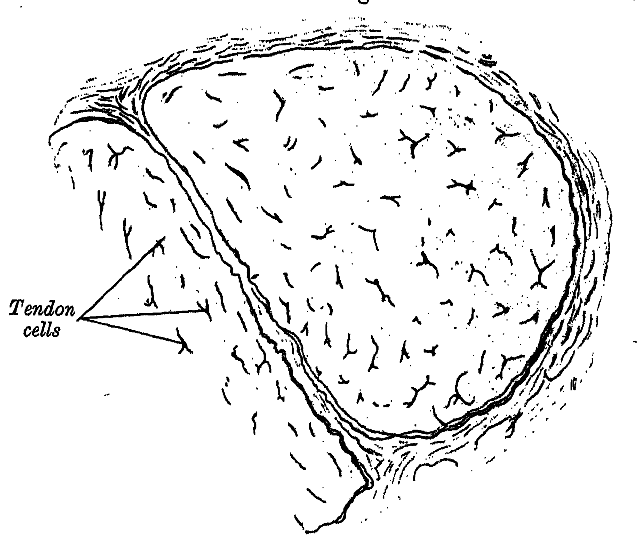


FIG. 18.—Tendon of a rat's tail, stained with gold chloride, showing chains of cells between the tendon-bundles. ×250.



exceedingly strong, so that upon the application of any external violence, a bone with which it is connected may fracture before the fibrous tissue gives way. In ligaments and tendons the bundles of fibres run parallel with each other; in membranes they intersect one another. The cells found in white fibrous tissue are often called 'tendon-cells.' They are situated on the surfaces of groups of fibres, and are arranged in rows, each cell being separated from its

FIG. 19.—A transverse section through a tendon of a rat. ×120.

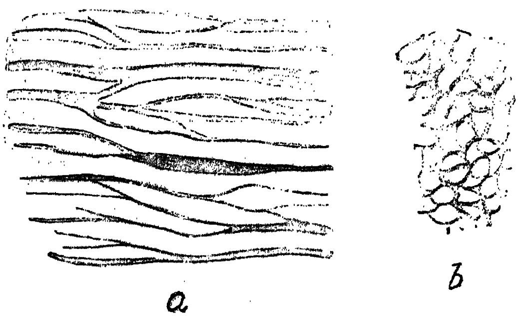


neighbours by a narrow line of cement-substance. The nucleus is generally situated at one end of the cell, the nucleus of the adjoining cell being in close proximity to it (fig. 18). The tendon-cells have wing-like processes which pass between the bundles of fibres, giving a stellate appearance in transverse section (fig. 19). When viewed from this side, the cell with its wings is quadrangular, and there may be the appearance of a vertical line on the body of the cell owing to the projection of a wing towards the eye of the observer (fig. 18). Upon the

addition of acetic acid, white fibrous tissue swells up into a glassy-looking indistinguishable mass. When boiled in water it is converted almost completely into gelatin, the white fibres being composed of *collagen*, which is regarded as the anhydride of gelatin.

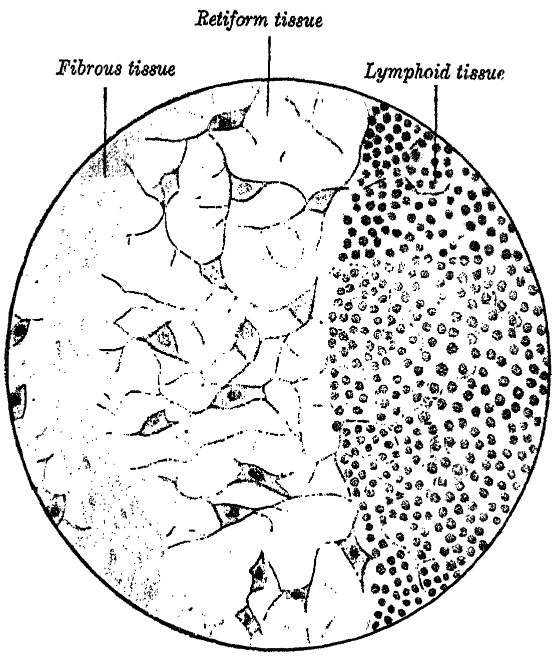
Yellow elastic tissue.—In certain parts of the body a tissue is found which is of a yellowish colour, and possessed of great elasticity. It is capable of considerable extension, and when the extending force is withdrawn returns at once to its original condition. This is *yellow elastic tissue*; it may be regarded as a connective tissue in which the yellow elastic fibres have developed to the practical exclusion of the other elements. It is found in the ligamenta flava, in the vocal folds and the crico-vocal membrane (conus elasticus), in the mucous membrane of the trachea and bronchi, in the walls of the pulmonary air-vesicles, in the coats of the blood-vessels, especially the larger arteries, and to a very considerable extent in the thyrohyoid and stylohyoid ligaments. It is also found in the ligamentum nuchæ of the lower animals (fig. 20). Where the fibres are

Fig. 20.—Ligamentum nuchæ of the ox, stained with picrocarmine. ×280.



a. Longitudinal section. *b.* Transverse section.

Fig. 21.—Retiform and lymphoid tissue from a lymph-gland, stained with picrocarmine. ×255.



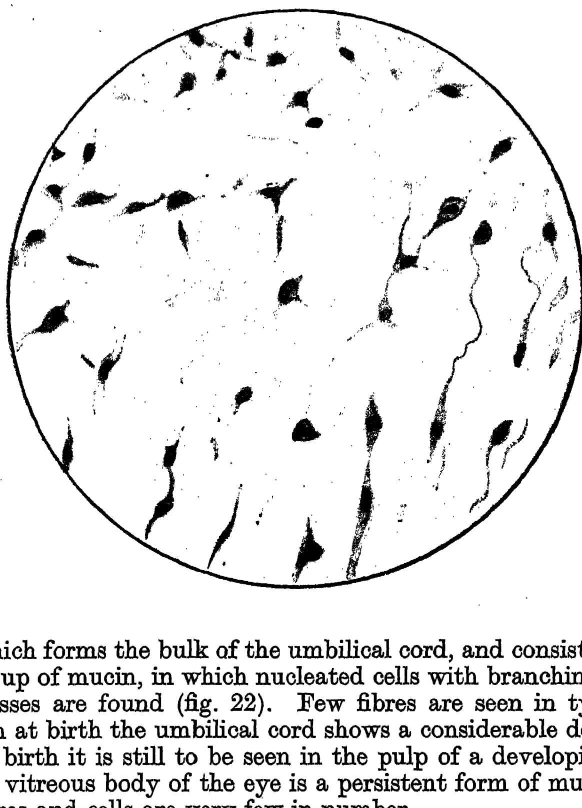
broad and large and the network close, the tissue presents the appearance of a membrane, with gaps or perforations corresponding with the intervening spaces. This is found in the inner coat of the arteries, and to it the name of *fenestrated membrane* has been given by Henle. Yellow elastic fibres remain unaltered by acetic acid; chemically they are composed of the sclero-protein known as *elastin*.

Retiform or reticular tissue (fig. 21) is found extensively in many parts of

the body, constituting the framework of some organs and entering into the construction of many mucous membranes. It is a variety of connective tissue in which the intercellular or ground-substance is, in a great measure, replaced by fluid. It is composed almost entirely of extremely fine bundles of white fibrous tissue, forming an intricate meshwork, and chemically it yields *gelatin* on boiling. The fibres are covered and concealed in places by flattened branched connective tissue-cells. In many situations the interstices of the network are filled with rounded lymph-corpuscles, and the tissue is then termed **lymphoid tissue.**

Mucoid tissue is a fœtal or embryonic type of connective tissue, found chiefly as a stage in the development of connective tissue. It exists in the 'jelly of

FIG. 22.—Mucoid tissue from the umbilical cord of a human fœtus of four months, stained with hæmatoxylin and eosin. ×255.



Wharton,' which forms the bulk of the umbilical cord, and consists of a matrix, largely made up of mucin, in which nucleated cells with branching and anastomosing processes are found (fig. 22). Few fibres are seen in typical mucoid tissue, though at birth the umbilical cord shows a considerable development of fibres; after birth it is still to be seen in the pulp of a developing tooth. In the adult the vitreous body of the eye is a persistent form of mucoid tissue, in which the fibres and cells are very few in number.

Pigmented connective tissue-cells are frequently met with in the lower vertebrates. In man they are found in the choroid coat of the eye (fig. 23), and in the iris of all but the light blue eyes and the albino. The cells are usually large and branched, and are filled with brown or black granules, consisting of *melanin.* In the retina the processes of the cells extend between the rods and cones; when the eye is exposed to light the pigment-granules extend into these processes, and under the influence of darkness they are withdrawn into the body of the cell.

The pigment-granules are of very small size and are closely packed within the cells, but do not invade the nuclei. Occasionally they are yellow, and when occurring in the cells of the cuticle constitute 'freckles.' In the retina another variety of pigment occurs, known as *rhodopsin* or *visual purple,* which is bleached on exposure to light.

Applied Anatomy.—Congenital absence of pigment from the skin and other tissues constitutes the condition known as albinism. Localised patches of skin from which pigment is absent are found in leucoderma; linear white streaks may result from old scars or from

overdistension of the skin, particularly that over the abdomen following pregnancy or ascites. A congenital excessive pigmentation may be general, or may occur locally in the form of dark brown or black nævi (moles). Pigmented patches occasionally follow the continued action of local irritants, and a general swarthiness may result from excessive exposure to the sun, particularly in association with uncleanliness (vagabondinismus). A rare form of general pigmentation ensues on the prolonged administration of salts of silver or of arsenic. Disorders of the endocrine organs may be associated with much discoloration of the skin; this is particularly noticeable in Addison's disease (suprarenal glands) where the pigmentation occurs mostly on the face, exposed parts of the neck, backs of hands, axillary and umbilical regions, genital organs, and medial surfaces of the thighs, but invades also the buccal and lingual mucous membranes. In pregnancy and in some uterine disorders patches of discoloration may be seen round the nipples, over the linea alba, and on the face. Many chronic wasting diseases are accompanied by peculiar colorations of the skin, notably cancer and phthisis; in the latter there may be much deepening of the tint over the zygomatic bones and round the orbits.

Basement-membranes consist of thin sheets of modified connective tissue, and are found underlying layers of epithelial cells, for example, in mucous membranes and secreting glands. They may be formed of cells or of condensed ground-substance. In the former case, flattened cells, which are modified

FIG. 23.—Pigmented connective tissue cells.

connective tissue corpuscles, are united by their edges by means of cement-substance, which can be demonstrated by staining with silver nitrate; if the cells are unbranched, the membrane is continuous; if they are branched, the processes are united, and the membrane is fenestrated. The basement-membrane underlying the epithelium on the anterior surface of the cornea is composed of ground-substance.

Vessels and nerves of connective tissue.—The *blood-vessels* of connective tissue are very few—that is to say, few are supplied to the tissue itself, although many carrying blood to other structures may permeate one of its forms, viz. areolar tissue. In white fibrous tissue the blood-vessels usually run parallel to and between the longitudinal bundles, sending communicating branches across the bundles; in some forms, as in the periosteum and dura mater, they are fairly numerous. In yellow elastic tissue the blood-vessels also run between the fibres. *Lymphatic vessels* are very numerous in most forms of connective tissue, especially in the areolar tissue beneath the skin and the mucous and serous surfaces. They are also found in abundance in the sheaths of tendons, as well as in the tendons themselves. *Nerves* are found in white fibrous tissue, where they end in a special manner; but it is doubtful whether any nerves end in areolar tissue; at all events, they have not yet been demonstrated, and the tissue is possessed of very little sensibility.

Cartilage

Cartilage is a variety of connective tissue in which the ground-substance has become solidified. It is a non-vascular structure found in various parts of the body—in the joints, parietes of the thorax, trachea, bronchi, nose, and ears—where it is necessary to have rigidity and strength combined with a certain degree of elasticity. In the fœtus, at an early period, the greater part of the skeleton is cartilaginous; as this cartilage is afterwards replaced by bone, it is called *temporary*, in contradistinction to that which remains unossified and is called *permanent*.

Cartilage is divided, according to its minute structure, into *hyaline cartilage*, *white fibrocartilage*, and *yellow* or *elastic fibrocartilage*. Besides these varieties met with in the adult human subject, there is a variety called *cellular cartilage*, formed entirely, or almost entirely, of cells, separated from each other by their capsules only, which are extremely well marked in this kind of cartilage. Cellular cartilage is found in the external ears of rats, mice, and some other animals, and it also forms a stage in the development of cartilage in human embryonic life.

FIG. 24.—Cartilage-cells in the costal cartilage of a kitten, stained with picrocarmine. ×350.

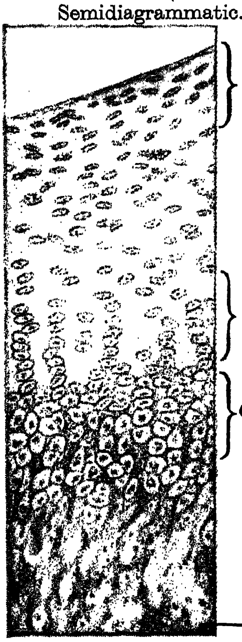
Hyaline cartilage has a pearly bluish colour and consists of a gristly mass of a firm consistence, but of considerable elasticity. Except where it coats the articular ends of bones it is covered by a fibrous membrane, named the *perichondrium*, from the vessels of which it imbibes its nutritive fluids, being itself destitute of blood-vessels. It contains no nerves. If a thin slice be examined under the microscope, it is seen to consist of cells of a rounded or bluntly angular form, lying in spaces in a granular or almost homogeneous matrix (fig. 24). The cells are frequently arranged in groups of two or more, and, when this is so, they have generally straight outlines where they are in contact with each other, but are rounded in the rest of their circumference. They consist of clear translucent protoplasm in which fine interlacing filaments and minute granules are sometimes present; one or two round nuclei, having the usual intranuclear network, are imbedded in the protoplasm.

The matrix is transparent and apparently without structure, or else presents a dimly granular appearance, like ground glass. The portion immediately surrounding each cell-space is often well-defined, and is further characterised by its affinity for basic dyes. It is known as the *capsule* of the space. The matrix of hyaline cartilage, and especially that of the articular variety, can be broken up into fine fibrils after prolonged maceration. These fibrils are probably of the same nature, chemically, as the white fibres of connective tissue. It is believed

by some histologists that the matrix is permeated by a number of fine channels which connect the cell-spaces with each other and with the lymphatics of the perichondrium, and that in this way nutrient fluid obtains access to the cartilage-cells.

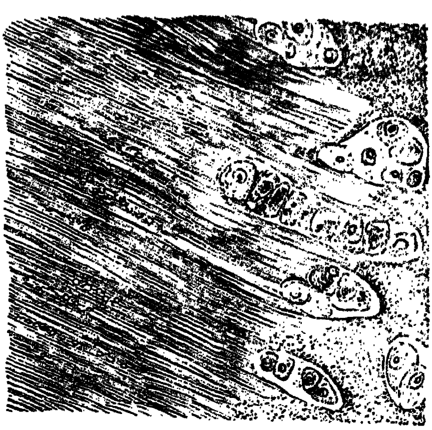
Costal cartilage, temporary cartilage and most of the articular cartilage are of the hyaline variety, but they present differences in the size, shape, and arrangement of their cells.

FIG. 25.—A vertical section through the lower end of the ulna of a human fœtus. Semidiagrammatic.



Articular hyaline cartilage (fig. 25) shows no tendency to ossification; its matrix is finely granular, and its cells are flattened and disposed parallel to the surface in the superficial part of the cartilage, while nearer to the bone they are oval and are arranged in vertical rows. It has a tendency to split in a vertical direction. Its free surface is not covered by perichondrium, but the synovial membrane can be traced over a small part of its circumference, and here the cartilage-cells are more or less branched and pass insensibly into the branched connective tissue cells of the synovial membrane. It forms a thin layer upon the joint-surfaces of the bones, and its elasticity enables it to break the force of concussions, while its smoothness gives ease and freedom of movement. It varies in thickness according to the shape of the articular surface on which it lies; where this is convex the cartilage is thickest at the centre, the reverse being the case on concave articular surfaces. The free surface of the cartilage is constantly being worn away throughout life owing to the joint movements, and this wastage necessitates continuous maintenance growth. In the child mitosis is the normal method of cell division, but at an early age amitotic figures can be observed and in the adult amitosis is the sole mechanism responsible for growth.* Articular cartilage appears to derive its nutriment partly from the vessels of the synovial membrane, partly from those of the bone upon which it is implanted, and possibly from the synovial fluid. The minute vessels of the spongy bone dilate and form arches as they approach the articular lamella, and then return into the substance of the bone.

FIG. 26.—Costal cartilage from a man seventy-six years of age, showing the development of fibrous structure in the matrix. In several portions of the specimen two or three generations of cells are seen enclosed in a parent cell-wall. Highly magnified.



In costal cartilage the cells and nuclei are large, and the matrix, which is usually homogeneous and transparent, has a tendency to fibrous striation, especially in old age (fig. 26). In the thickest parts of the costal cartilages a few large vascular channels may be detected. This appears, at first sight, to be an exception to the statement that cartilage is non-vascular, but is not so

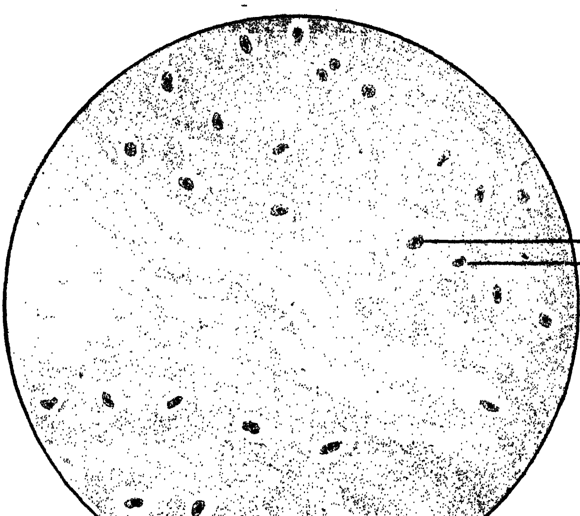
* H. C. Elliott, "Studies on Articular Cartilage," *American Journal of Anatomy*, vol. 58, 1936.

in reality, for the vessels give no branches to the cartilage itself, and the channels may rather be looked upon as involutions of the perichondrium. The xiphoid process of the sternum and the cartilages of the nose, larynx, and trachea (except the epiglottis and corniculate cartilages of the larynx, which are composed of elastic fibrocartilage) resemble the costal cartilages in microscopical characteristics. The arytenoid cartilage of the larynx shows a transition from hyaline cartilage at its base to elastic cartilage at the apex.

The hyaline cartilages, especially in adult and advanced life, are prone to calcify—that is to say, their matrix becomes permeated by calcium salts. Calcification occurs frequently in the costal cartilages, and in the cartilages of the trachea, and may be succeeded by ossification.

White fibrocartilage consists of white fibrous tissue arranged in bundles, with cartilage-cells between the bundles ; the cells are roughly ovoid in shape, and are surrounded by concentrically striated areas of cartilage-matrix (fig. 27). The white fibrocartilages admit of arrangement into five groups—interarticular, connecting, circumferential, stratiform and articular.

FIG. 27.—White fibrocartilage from the intervertebral disc of a sheep, stained with borax-carmine. ×300.



1. The *interarticular fibrocartilages* are flattened fibrocartilaginous plates, of a round, oval, triangular, or sickle-like form, interposed between the articular cartilages of certain joints ; the synovial membrane of the joint covers their free surfaces, where they are not exposed to pressure. They are found in the mandibular, sternoclavicular, acromioclavicular, wrist- and knee-joints. They serve to obliterate the intervals between opposed surfaces in their various motions and to adapt articular surfaces to one another.*

2. The *connecting fibrocartilages* are interposed between the bony surfaces of those joints which admit of only slight mobility, as between the bodies of the vertebræ. They form discs which are closely adherent to the opposed surfaces. Each disc is composed of concentric layers of white fibrous tissue, with cartilaginous laminæ interposed, the former tissue predominating towards the circumference, the latter towards the centre.

3. The *circumferential fibrocartilages* consist of rims of fibrocartilage which surround the margins of some of the articular cavities, e.g. the glenoidal labrum of the shoulder-joint and the acetabular labrum of the hip-joint ; they serve to deepen the articular cavities and to protect their edges.

* *See also* p. 427.

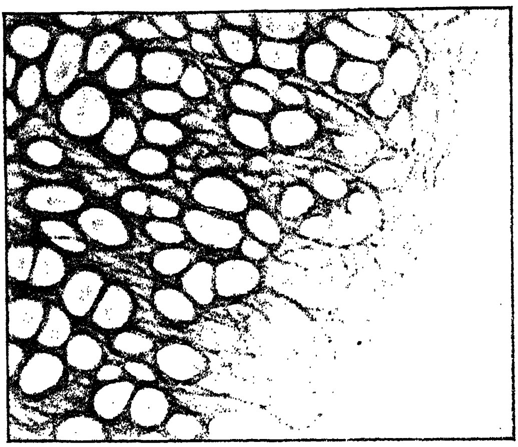
4. The *stratiform fibrocartilages* form thin coatings to osseous grooves through which the tendons of certain muscles glide.

Small masses of fibrocartilage are also developed in the tendons of some muscles, where they glide over bones, as in the tendons of the peroneous longus and tibialis posterior.

5. *Articular fibrocartilage* covers the articular ends of bones which ossify in membrane. In the floor of the articular fossa of the temporal bone the covering consists mainly of white connective tissue fibres, and the cartilage-cells are few in number.

Yellow or elastic fibrocartilage is found in the ears, the corniculate cartilages of the larynx, and the epiglottis. It consists of cartilage-cells and a matrix, the latter being pervaded by a network of yellow elastic fibres, branching and anastomosing in all directions, except immediately around the cells, where there is a variable amount of hyaline substance (fig. 28). The fibres resemble those

FIG. 28.—Yellow or elastic fibrocartilage from the ear of a sheep, stained with orcein.



of yellow elastic tissue, not only in appearance, and in being unaffected by acetic acid, but also in their affinity for orcein; according to Rollett their continuity with the elastic fibres of the neighbouring tissue is demonstrable.

The distinguishing feature of cartilage, chemically, is that on boiling it yields a substance called *chondrin*, a mixture of gelatin with mucinoid substances, chief among which is a compound termed *chondromucoid*.

BONE

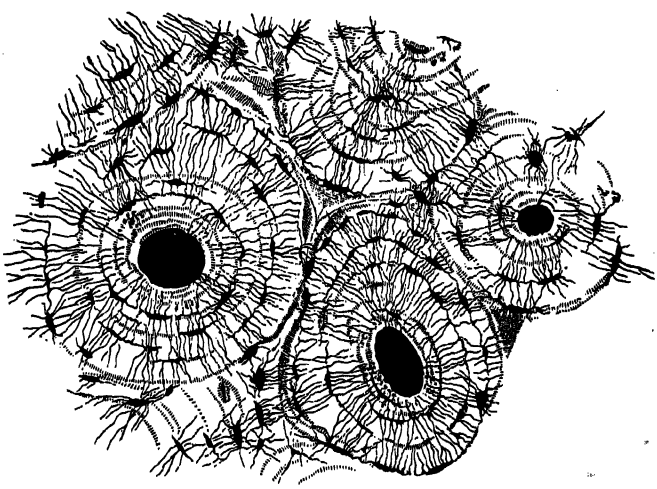
Structure and physical properties.—Bone is a variety of connective tissue which is characterised by the presence of certain inorganic salts in its ground substance. It is one of the hardest structures of the animal body, although it possesses also a certain degree of toughness and elasticity. Its colour, in a fresh state, is pinkish white externally, and deep red within. In section it is seen to be composed of two kinds of tissue, one of which is dense in texture, like ivory, and is termed *substantia compacta*; the other consists of slender fibres and lamellæ, which join to form a reticular structure, and is called *substantia spongiosa*. The compact substance is always placed on the exterior of the bone, the spongy in the interior (fig. 263). The relative quantities of these vary in different bones and in different parts of the same bone, according as strength or lightness is requisite. Close examination of the compact substance shows it to be extremely porous, so that the difference between it and the spongy substance depends merely upon the relative amount of solid matter and the size and number of spaces in each; in the compact substance the spaces are small and the solid matter abundant, while in the spongy substance the spaces are large and the solid matter small in quantity.

During life bone is permeated by vessels, and enclosed, except where it is coated with articular cartilage, in a fibrous membrane termed the *periosteum*, by means of which many of these vessels reach the bone. If the periosteum be stripped from the surface of the living bone, small bleeding points are seen which mark the entrance of the periosteal vessels; and on section every part of the bone exudes blood from the minute vessels which ramify in it. In the interior of the long bones of the limbs there is a cylindrical cavity (*cavum medullare*) filled with *medulla ossium* or *marrow*, and lined with a membrane composed of highly vascular areolar tissue, called the *endosteum*.

The **periosteum** adheres to the surfaces of the bones but it is absent from the cartilage covering their articular surfaces. When strong tendons or ligaments are attached to a bone, the periosteum is incorporated with them. It consists of two layers closely united together, the outer formed chiefly of white fibrous tissue, containing occasionally a few fat-cells; the inner, of elastic fibres of the finer kind, forming dense membranous networks, which can again be separated into several layers. In young bones the periosteum is thick and very vascular, and is separated from the bone by a layer of soft *osteogenetic tissue*, containing a number of granular corpuscles or 'osteoblasts,' by which ossification proceeds on the exterior of the young bone. Later in life the periosteum is thinner and less vascular, and the osteoblasts are represented by a single layer of flattened cells on its deep surface. The periosteum serves as a nidus for the ramification of the vessels previous to their distribution in the bone; hence the liability of bone to exfoliation or necrosis when denuded of this membrane by injury or disease. Fine nerves and lymphatics, which generally accompany the arteries, may also be demonstrated in the periosteum.

Vessels and nerves of bone.—The *blood-vessels* of bone are very numerous. Those of the compact substance are derived from a close network of vessels in

FIG. 29.—A transverse section through the compact substance of bone. Magnified. (Sharpey.) (From Quain's Elements of Anatomy.)

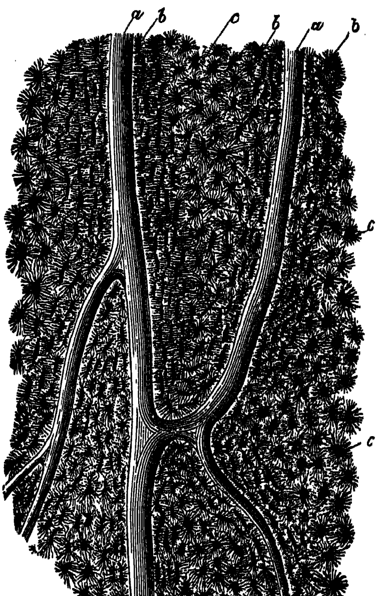


the periosteum. Vessels pass from this network into the minute orifices in the compact substance, and run in the Haversian canals which traverse it. The spongy substance is supplied in a similar way by larger vessels, which perforate the outer compact substance, and are distributed to the cavities of the spongy portion of the bone. In the long bones, numerous apertures may be seen at the ends near the articular surfaces; some of these give passage to arteries, but the greater number transmit veins from the spongy substance. The marrow of a long bone is supplied by an artery which enters the bone at the nutrient foramen (*foramen nutricium*). The *nutrient* artery, usually accompanied by one or two veins, sends branches upwards and downwards, which ramify in the endosteum, and give twigs to the adjoining Haversian canals. The ramifications of this vessel anastomose with the arteries of the spongy and compact substances. In

most of the flat, and in many of the short, bones there are one or more large apertures for the transmission of nutrient vessels. Veins emerge from the long bones as follows :—(1) one or two accompany the nutrient artery ; (2) numerous large and small veins emerge near the articular extremities ; (3) many small veins pass out of the compact substance. In the flat cranial bones the veins are large and run in tortuous canals in the diploic tissue, the walls of the canals being formed by thin lamellæ of bone, perforated here and there for the passage of branches from the adjacent diploë. The same condition is found in all spongy substance, the veins being enclosed and supported by osseous material, and having exceedingly thin coats. When a bone is divided, the vessels remain open, and do not contract in the canals in which they are contained. *Lymphatic vessels,* which communicate with those in the periosteum, are found in the Haversian canals. *Nerves* are distributed freely to the periosteum, and accompany the nutrient arteries into the interior of the bone. They are said to be most numerous in the articular extremities of the long bones, in the vertebræ, and in the larger flat bones.

Minute anatomy.—If a thin transverse section of dense bone be examined with a low power of the microscope it will be seen to be mapped out into a number of circular districts, each consisting of a central hole surrounded by a number of concentric rings. These districts are termed *Haversian systems*; the central hole is a *Haversian canal,* and the rings are *lamellæ* of bony tissue arranged concentrically around the central canal. Between these lamellæ there are a number of small spaces termed *lacunæ,* which are connected with each other and with the central Haversian canal by many fine radiating channels called *canaliculi*. The irregular intervals between these circular districts are occupied by *interstitial* lamellæ, with their lacunæ and canaliculi, running in various directions, but more or less parallel with the surface (fig. 29). Again, other lamellæ are found on the surface of the bone completely encircling it ; they are termed *circumferential* or *primary* lamellæ, to distinguish them from those surrounding the Haversian canals, which are termed *secondary* lamellæ.

FIG. 30.—A longitudinal section of the shaft of the femur. ×100.



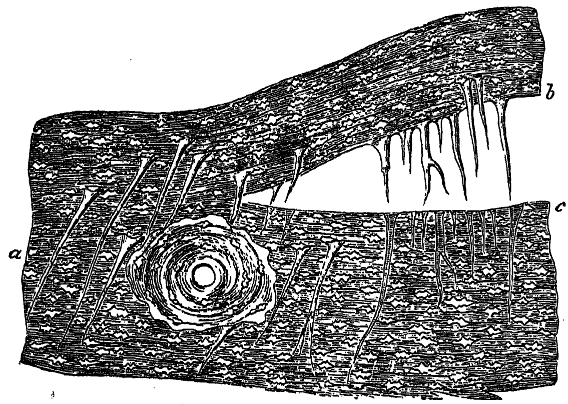
a. Haversian canals. *b.* Lacunæ seen from the side. *c.* Others seen from the surface in lamellæ which are cut horizontally.

In a longitudinal section it will be seen that the Haversian canals run parallel with the long axis of the bone but branch and communicate at short intervals (fig. 30). They vary considerably in size, but their average diameter is about 0·05 mm. The canals near the medullary cavity are larger than those near the surface of the bone. Each canal usually contains a minute artery and vein, a small quantity of delicate connective tissue, and some nerve-filaments ; in the larger ones there are also lymph vessels, and cells with branching processes.

The *lamellæ* are thin plates of bony tissue. They may be stripped off as thin films from a piece of bone which has been macerated in dilute mineral acid. If one of these films be examined with a high power of the microscope, it will be found to be composed of fine fibres identical with the white fibres of areolar tissue. The matrix between the fibres is impregnated with lime-salts which the acid dissolves. The fibres are arranged in bundles, and fibres leave the bundles of one lamella to join those of adjacent lamellæ. Moreover, the fibres of one lamella usually form an acute angle with those of the contiguous layer ; in the Haversian systems, however, the fibres of adjacent lamellæ

run at right angles to each other. In many places the various lamellæ are held together by tapering fibres, which run obliquely through them, pinning or bolting them together; these fibres were first described by Sharpey, and were named by him *perforating fibres* (fig. 31).

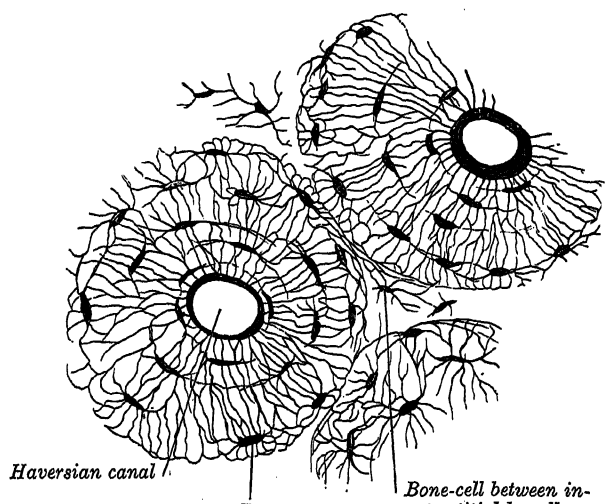
FIG. 31.—The perforating fibres of a human parietal bone, decalcified. (H. Müller.) (From Quain's Elements of Anatomy, vol. ii. pt. i., Microscopic Anatomy.)



a. Perforating fibres *in situ*; *b*. Fibres drawn-out of their sockets; *c*. Sockets.

The *lacunæ* are oblong spaces situated between the lamellæ, and each lacuna is occupied during life by a branched *bone-cell*, the processes from which extend into the canaliculi.

FIG. 32.—A transverse section through a portion of the shaft of a human fibula, decalcified. ×250.



The *canaliculi* are minute channels, crossing the lamellæ and connecting the lacunæ of a Haversian system with one another, and with the Haversian canal. The canaliculi at the periphery of a Haversian system do not as a rule communicate with those of neighbouring systems, but form loops and return to their own lacunæ. Thus every part of a Haversian system is supplied with nutrient fluids derived from the vessels in the Haversian canal and distributed through the canaliculi and lacunæ.

The *bone-cells* occupy, but do not fill, the lacunæ. They are flattened,

nucleated branched cells, homologous with the lamellar cells of connective tissue ; their branches pass into the canaliculi.

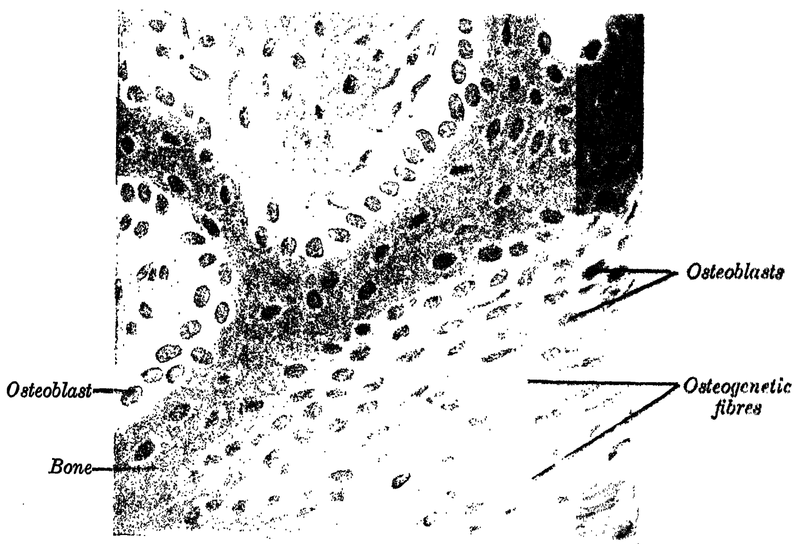
In thin plates of bone Haversian canals are absent.

Chemical composition.—Bone consists of animal or organic, and mineral or inorganic, substances intimately combined.

The animal substance forms about 33 per cent. of the total weight,* and may be obtained by immersing a bone for a considerable time in dilute mineral acid which will dissolve the mineral matter. The bone retains its shape, but is now perfectly flexible, so that a long bone (one of the ribs, for example) can easily be tied in a knot. In a transverse section of such a softened bone (fig. 32), the arrangement of the Haversian canals, lamellæ, lacunæ, and canaliculi can be recognised.

The mineral substance may be obtained by calcination, which destroys the animal matter. The bone retains its original form, but is white and brittle, has

Fig. 33.—Intramembranous ossification.



lost about one-third of its original weight, and crumbles under the slightest force. The mineral substance, composed chiefly of calcium phosphate, forms about 66·7 per cent. of the weight of the bone ; it confers on bone its hardness and rigidity, while the animal matter (*ossein*) determines its resiliency and tenacity.

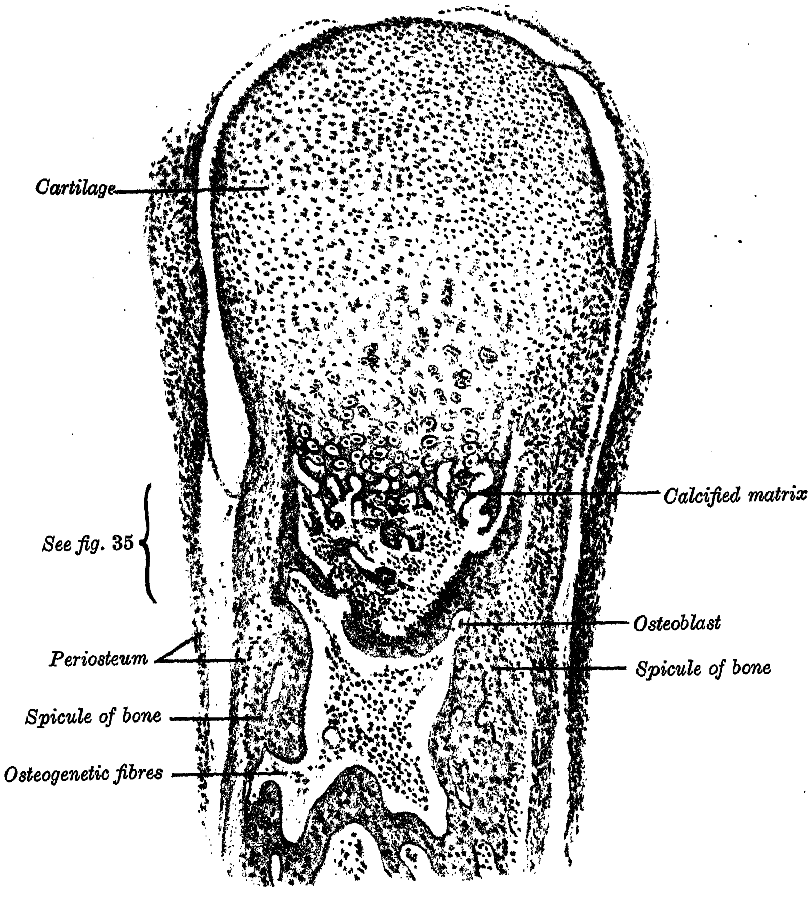
Ossification.—Some bones, such as those of the roof and sides of the skull, are preceded by membrane, but most bones are preceded by rods or masses of cartilage. Hence two kinds of ossification are described ; the *intramembranous* and the *intracartilaginous* ; but there is no essential difference between these two methods of bone formation.

Intramembranous ossification.—The membrane which occupies the place of the future bone is of the nature of connective tissue, and ultimately forms the periosteum ; it is composed of fibres and granular cells in a matrix richly supplied with blood-vessels. The peripheral portion is more fibrous, while in the central portion the cells or *osteoblasts* predominate. At the outset of the process of bone formation a little network of fibres radiates from the centre of ossification. These rays consist at their growing points of a network of fine clear fibres and granular corpuscles with an intervening ground-substance (fig. 33). The fibres are termed *osteogenetic* fibres, and differ little from those of white fibrous tissue. The membrane assumes a dark and granular appearance

* H. E. Radasch (*Proceedings of the American Association of Anatomists, Anatomical Record*, vol. 21) states that in ' green ' bone the organic substance averages 40·75 per cent.

from the deposition of calcareous granules in the matrix between the fibres, and in the calcified material some of the granular cells or osteoblasts are enclosed. By the fusion of the calcareous granules the tissue again assumes a more transparent appearance, but the fibres are no longer so distinctly seen. The osteoblasts form the bone-cells of the future bone, the spaces in which they are enclosed constituting the lacunæ. As this process advances, a network of bone is formed, the meshes of which contain the blood-vessels and a delicate connective tissue crowded with osteoblasts. The bony trabeculæ thicken by the addition of fresh layers formed by the osteoblasts on their surface, and the meshes are correspondingly encroached upon. Subsequently the bone increases in thickness

FIG. 34.—A section through a phalanx of a fœtal finger. ×100. Drawn from a specimen prepared by A. F. Bernard Shaw.



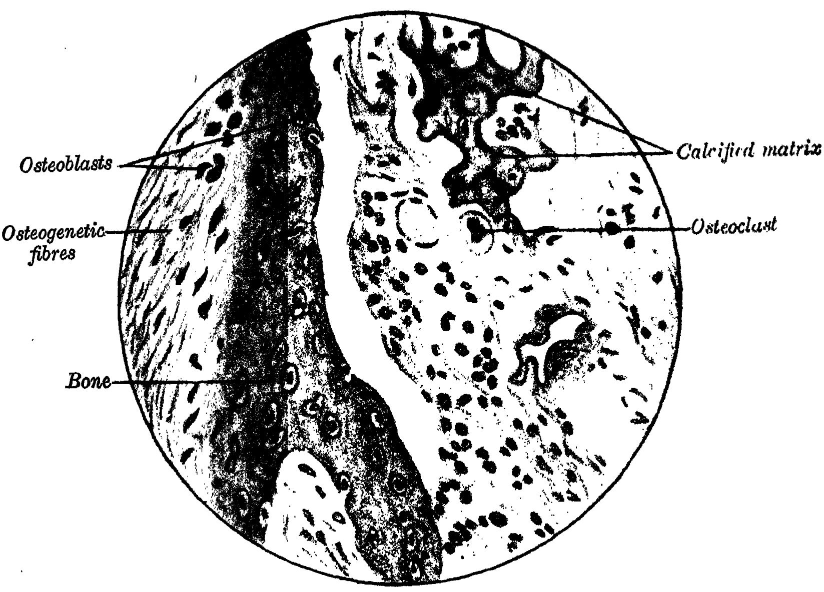
by the deposition of successive layers under the periosteum and round the larger vascular channels, which become the Haversian canals.

Intracartilaginous ossification.—Most of the bones are preformed in cartilage, and each long bone is represented in early fœtal life by a rod of hyaline cartilage. The *primary centre of ossification* appears in the centre of the rod and the process of bone formation extends towards the ends, which remain cartilaginous for a length of time which differs for different bones. Later, ossification begins at one or more *secondary centres* in one or both ends and the portions of bone formed from them constitute *epiphyses*. Most long bones develop an epiphysis at each extremity, but in some (metacarpals, metatarsals, phalanges and ribs) an epiphysis is formed at one end only. The cartilage which intervenes between

the epiphysis and the growing shaft or *diaphysis* is termed the *epiphyseal cartilage*.

The rodlike cartilage model of the bone is surrounded by a very vascular membrane, termed the *perichondrium*, which is formed by connective tissue similar to that already described as constituting the basis of membrane bone. Between this membrane and the underlying cartilage there is a layer of osteogenetic mesenchyme, from which the formative-cells (the *osteoblasts*) are derived. Prior to the appearance of the primary centre of ossification the cartilage-cells in the middle of the shaft become greatly enlarged and the trabeculae between them become reduced to thin partitions. The cartilage-cells, possibly owing to autointoxication due to absorption of the surrounding matrix during the period of growth, undergo degenerative changes and die. Their bodies become shrunken and leave spaces which are termed the *primary areolæ*. Subsequent to the death of their parent cells the thin partitions between these spaces become calcified.

FIG. 35.—A part of fig. 34 (opposite to the bracket) more highly magnified. ×375.



The weakening of the shaft brought about in this way is compensated for by the subperichondral osteoblasts, which lay down a peripheral layer of young bone by the intramembranous method previously described. These changes constitute the first stage in the process of intracartilaginous ossification.

The second stage consists in the prolongation into the cartilage of processes of the deeper or osteogenetic layer of the perichondrium (now periosteum) (fig. 34). The processes consist of blood-vessels and cells—*osteoblasts*, or bone-formers, and *osteoclasts*, or bone-destroyers. The latter are large, multinucleated protoplasmic masses, and they excavate passages through the new-formed bony layer by absorption, and pass through it into the calcified matrix. Wherever these processes of the osteogenetic layer come in contact with the calcified walls of the primary areolæ they absorb them, and thus cause a fusion of the original cavities and the formation of larger spaces, which are termed the *secondary areolæ* or *medullary spaces*. These secondary spaces are filled with embryonic marrow, consisting of osteoblasts and vessels, derived, in the manner described above, from the osteogenetic layer of the periosteum.

The walls of the secondary areolæ increase in thickness by the deposition of layers of bone on their surface. This process takes place in the following manner. Some of the osteoblasts of the embryonic marrow, after undergoing rapid division, arrange themselves as a layer on the surface of the wall of the space (fig. 34). This layer of osteoblasts forms a bony stratum, which gradually

covers the wall of the space and in which some of the osteoblasts are included as bone-cells. The next stage in the process consists in the removal of these primary bone-spicules by the osteoclasts, one of which may be seen lying in a Howship's foveola at the free end of each spicule (fig. 35). The removal of the primary spicules goes on *pari passu* with the formation of permanent bone by the osteogenetic layer of the periosteum, and in this way the medullary cavity of the bone is formed.

While bone is being laid down in the middle of the shaft the adjoining cartilage reacts in a manner which prepares it for the extension of the ossifying process. In the area directed towards the end where an epiphysis appears later, the cartilage cells undergo rapid division, at first in the transverse axis of the bone and then in its long axis, so as to give rise to a great number of parallel rows of disc-shaped cells. This process goes on throughout the period of growth and is responsible for increase in length of long bones.* The older cells, which lie nearest to the primary centre of ossification, become hypertrophied and this enlargement is assocated with the intracellular storage of glycogen.† Most, if not all, of these distended cells die, the trabeculae between the columns undergoing calcification. Osteoclasts and osteoblasts from the primary centre extend the process of ossification in the longitudinal direction by invading the columns, removing the trabeculae and laying down new bone. As ossification extends along the shaft the cartilage-cells at the epiphyseal end of the rows divide rapidly, while those at the opposite end progressively hypertrophy and atrophy.

This series of changes proceeds gradually towards the ends of the bone, so that all the changes described above may be seen in different parts, from the true bone at the centre of the shaft to the hyaline cartilage at the extremities.

While the ossification of the cartilaginous shaft is extending towards the articular ends, the epiphyseal cartilage immediately in advance of the bony tissue continues to grow until the length of the adult bone is reached.

One or more secondary bony centres appear in the cartilaginous extremities and initiate in them the process of ossification ; but the ends remain separated from the shaft of the bone by the epiphyseal cartilages for a definite time. Ossification of epiphyses and ossification of the diaphysis in the direction of an extremity where no epiphysis develops (e.g. the distal ends of the phalanges, etc.) are not marked by the preliminary formation of rows of cells.‡ Instead, the cartilage-cells constitute small groups or cell-nests, which undergo hypertrophy and, later, die, a change accompanied by calcification of the surrounding matrix. These groups become invaded by osteoblasts and osteoclasts and bone is laid down in the manner already described. The epiphyseal cartilages ultimately ossify, and the bone assumes its completed form and shape. The same remark applies to such processes of bone as are ossified from separate epiphyses, e.g. the trochanters of the femur. Bones increase in length by ossification continuing to extend into the epiphyseal cartilages, which go on growing in advance of the ossifying process ; when the growth of the epiphyseal cartilages ceases, the diaphysis and the epiphyses unite. Bones increase in circumference by deposition of new bone from the osteogenetic layer on their sub-periosteal aspects, and at the same time an absorption takes place from within, by which the medullary cavities are increased. It should be observed that, in certain situations, e.g. the ramus of the mandible (p. 282) and the expanded extremities of the shafts of the long bones, a process of remodelling is necessary during the stage of lengthening, in order that the outline of the bone may remain constant throughout the period of growth. This remodelling is brought about by a process of absorption, which goes on side by side with the process of deposition and is an essential feature of normal growth in the situations cited.

The bone first laid down is spongy in structure. Later the osteoblasts contained in its spaces form the concentric layers characteristic of the Haversian systems, and are included as bone-cells.

The number of ossific centres varies in different bones. Most of the short

* C. W. Stump, *Journal of Anatomy*, vol. lix. 1925.

† *See* H. A. Harris, *Bone Growth in Health and Disease*, 1933.

‡ G. S. Dodds, *Anatomical Record*, vol. 46, No. 4, and *cf.* H. A. Harris, *loc. cit.*

bones are ossified from a single centre. In each long bone there is a primary centre for the shaft, or diaphysis; and one or more secondary or epiphyseal centres for each extremity. That for the shaft is the first to appear. The times of union of the epiphyses with the shaft vary inversely with the dates at which their ossifications begin (with the exception of the fibula) and regulate the direction of the nutrient arteries of the bones. Thus, the nutrient arteries of the bones of the arm and forearm are directed towards the elbow, since the epiphyses at this joint become united with the shafts of the bones before those at the opposite extremities. In the lower limb, on the contrary, the nutrient arteries are directed away from the knee; that is, upwards in the femur, downwards in the tibia and fibula; and in them it is observed that the epiphyses at the upper end of the femur, and those at the lower ends of the tibia and fibula, unite first with the shafts. Where there is only one epiphysis, the nutrient artery is directed towards the other end of the bone. The growing end of the macerated diaphysis has a curious coral-like appearance, which is quite characteristic.

Epiphyses are essentially a mammalian characteristic, for, apart from the upper tibial epiphysis occurring in birds and some reptiles, they do not occur in lower vertebrates.* There is, however, reason to believe that they were present in the extinct group of mammal-like reptiles.† Their presence at the expanded ends of the long bones reduces very considerably the amount of remodelling by absorption which would be necessary, if they did not develop. Parsons ‡ groups epiphyses under three headings, viz. (1) *pressure epiphyses*, appearing at the articular ends of the bones and transmitting 'the weight of the body from bone to bone'; (2) *traction epiphyses*, associated with the insertion of muscles, and 'originally sesamoid structures though not necessarily sesamoid bones'; and (3) *atavistic epiphyses*, representing parts of the skeleton which at one time formed separate bones, but which have lost their function 'and only appear as separate ossifications in early life.'

The description here given of the development and growth of bone is in accordance with the generally accepted view. Macewen § has, however, given another account. He asserts that the osteoblasts are produced by division of the nuclei of the cartilage-cells, and that bone-formation is brought about by these cells, the periosteum taking no part in the process. He concludes that the function of the periosteum in the development of bone is mechanical, and is confined to limiting the degree of growth and deciding its direction.

Applied Anatomy.—The blood supply of long bones is derived from two sources: (*a*) one (occasionally more) nutrient artery runs through the compact outer layer to reach the medulla where it is distributed; (*b*) a network of vessels in the periosteum anastomoses with the twigs of the nutrient artery and gives branches to the ends of the bone. In young bones the diaphyseal vessels do not penetrate the epiphyseal cartilage, and the epiphysis receives an independent blood supply from the vessels of the capsule of the joint.

Many of the periosteal vessels reach the periosteum through the attachments of the muscles, so that when the latter are well-developed and their blood-supply abundant the periosteum is also well supplied with blood and the bones are strongly developed with prominent ridges. Conversely if the muscular development is poor the bones are thin and light. This is strikingly demonstrated in cases of infantile paralysis where several muscles of a limb become paralysed at an early period of childhood. The periosteal blood-supply suffers and consequently very little fresh osseous tissue is added to the outer surfaces of the bones. In such cases although the limb continues to grow in length at the epiphyseal cartilages, its length is less than that of the normal side; but the most striking feature of the bones is their extreme thinness.

Since increase in the length of a bone depends on continued growth at the epiphyseal cartilages, it is necessary that great care should be taken not to interfere with these in dealing with disease in the neighbourhood of an epiphysis. A knowledge of the periods when the epiphyses join the diaphyses is often of importance in medico-legal enquiries. It is also of practical utility in deciding the nature of an injury in the neighbourhood of a joint, since separation of an epiphysis may simulate a fracture or a dislocation. Further, when amputation through one of the long bones is called for in a young subject the activity

* *Bone Growth in Health and Disease*, by H. A. Harris, 1933.

† *Origin of the Human Skeleton*, by R. Broom, 1930.

‡ *Journal of Anatomy and Physiology*, vols. xxxviii., xxxix., and xlii.

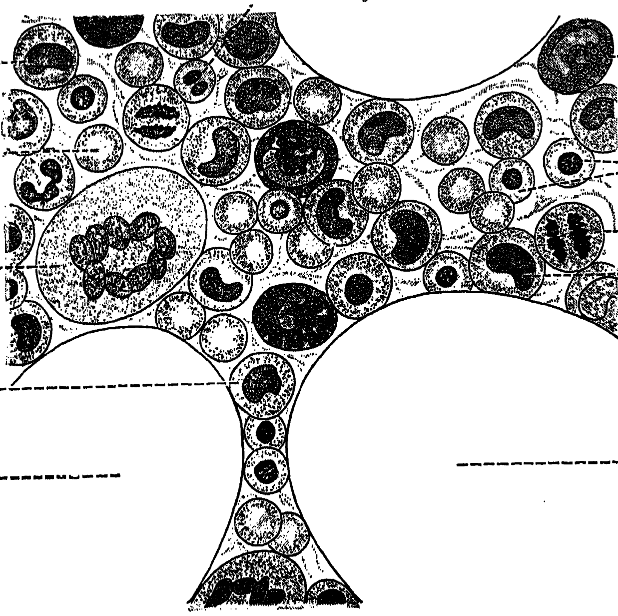
§ *The Growth of Bone*, by Sir William Macewen.

of growth at the epiphyseal cartilage must be borne in mind. As special cases, amputation through the humerus or tibia may be cited, since in these bones the proximal epiphyses are late in joining the diaphyses. If sufficient allowance be not made for this by cutting long flaps, the portion of the diaphysis remaining will continue to grow till its distal end projects through the stump—a condition known as *conical stump*.

Severe illnesses, occurring during the period of active growth of the long bones, cause a temporary arrest of growth which can be recognised later in radiograms as a dense line of bony deposition. This is succeeded by a zone of renewed growth in which it may be possible to detect that the bone laid down during convalescence was poorly differentiated.*

Premature arrest of growth of the epiphyseal cartilages results in too early junction of the epiphyses with the diaphyses (*premature synostosis*). This brings to an end the growth in length of the bones, and is one of the causes of dwarfism. Persons in whom this has occurred will have the head and trunk of normal size, but the legs and arms disproportionately short though often very strong.

FIG. 36.—Human bone-marrow. Highly magnified.



The **medulla ossium** or **bone marrow** is a variety of connective tissue in which the individual cells are the most important constituents. It not only fills up the cylindrical cavities in the bodies of the long bones, but also occupies the spaces of the cancellous tissue and extends into the larger Haversian canals. It differs in composition in different bones. In the shafts of the long bones the marrow is of a *yellow* colour (*medulla ossium flava*), and consists of a basis of connective tissue supporting numerous blood-vessels and cells, most of which are fat-cells, but some are 'marrow-cells,' such as occur in the red marrow. In the flat and short bones, in the articular ends of the long bones, in the bodies of the vertebræ, in the cranial diploë, in the sternum and ribs, the marrow is of a *red* colour (*medulla ossium rubra*).† Red marrow consists of a small quantity of connective tissue, blood-vessels, and numerous cells (fig. 36), a few of which are fat-cells but the great majority are spherical, nucleated cells, termed *myelocytes* or *marrow-cells*. The myelocytes resemble the leucocytes of the blood, and like them are amœboid; they contain granules, either oxyphil, basiphil or neutrophil in reaction. A number of eosinophil cells and a few basiphil cells are also present. Amongst the myelocytes smaller nucleated cells, of a yellowish colour, may be seen; these are the *erythroblasts* or *normoblasts* from which the

* H. A. Harris, *Arch. Int. Med.* vol. xxxviii.

† Alfred Piney (*Lancet*, Sept. 9th, 1922, p. 572) has investigated the naked-eye anatomy of the bone marrow in 1700 post-mortem cases, and concludes that all the bones, except those of the cranium, contain red marrow until puberty.

red corpuscles of the blood are derived by the disappearance of the nuclei. Giant-cells (*myeloplaxes* or *megakaryocytes*) similar to the osteoclasts described in connexion with the development of bone are also found in red marrow. In post-natal life the red marrow is the chief seat of the formation of the corpuscles of the blood.

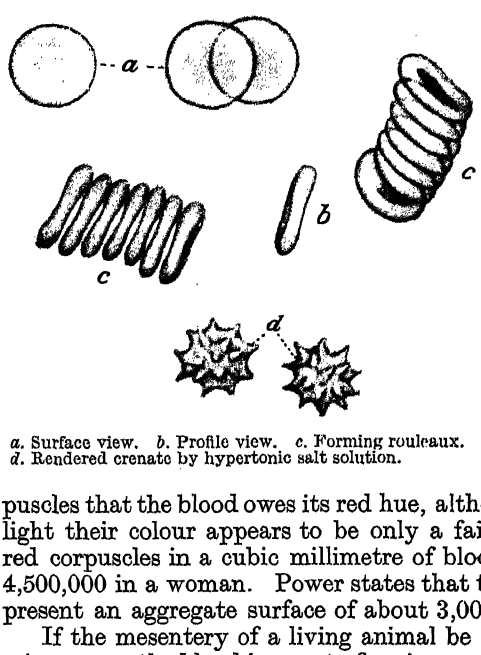
The **blood** is a variety of connective tissue, in which the ground substance is fluid and the constituent cells are highly specialised. It is opaque, rather viscid, of a bright red or scarlet colour when it flows from the arteries, of a dark red or purple colour when it flows from the veins. It is salt to the taste, and has a peculiar faint odour and an alkaline reaction. Its specific gravity is about 1·059, and its temperature is generally about 37° C., though varying slightly in different parts of the body.

If a thin film of blood be examined under the microscope it is seen to consist of a faintly yellow fluid—the *plasma* or *liquor sanguinis*—in which are suspended numerous minute particles—the *blood-corpuscles*.

The **blood-corpuscles** are of three kinds : (1) coloured corpuscles or erythrocytes, (2) colourless corpuscles or leucocytes, (3) blood-platelets.

1. The **coloured or red corpuscles** (*erythrocytes*) are circular discs, biconcave in profile. The disc has no nucleus, but, in consequence of its biconcave shape, it presents, when seen on the flat, a central area which, when the more prominent peripheral zone of the corpuscle is in focus, appears dark, and so simulates a nucleus (fig. 37, *a*). The corpuscles vary slightly in size even in the same drop of blood, but the average diameter of each is about 7·5μ, and the thickness about 2μ. Besides these there are certain smaller corpuscles of about one-half of the size just indicated ; these are termed *microcytes*, and are very scarce in normal blood ; in diseased conditions (e.g. anæmia), however, they are more numerous. It is to the aggregation of the red corpuscles that the blood owes its red hue, although when examined by transmitted light their colour appears to be only a faint reddish yellow. The number of red corpuscles in a cubic millimetre of blood is about 5,000,000 in a man, and 4,500,000 in a woman. Power states that the red corpuscles of an adult would present an aggregate surface of about 3,000 square yards.

FIG. 37.—Human red blood-corpuscles. ×1500.



a. Surface view. *b*. Profile view. *c*. Forming rouleaux. *d*. Rendered crenate by hypertonic salt solution.

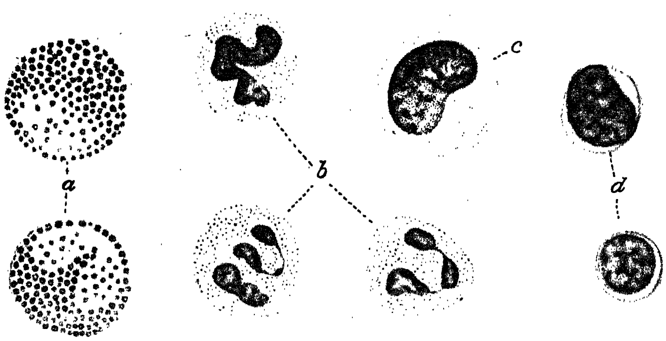
If the mesentery of a living animal be spread out and examined under the microscope, the blood is seen to flow in a continuous stream through the vessels, and the corpuscles show no tendency to adhere to each other or to the walls of the vessels. But when blood is drawn and examined on a slide, the corpuscles tend to collect into heaps like rouleaux of coins (fig. 37, *c*). During life the red corpuscles may be seen to change their shape under pressure so as to adapt themselves, to some extent, to the size of the vessel. They are, however, highly elastic, and speedily regain their form when the pressure is removed. They are readily influenced by the medium in which they are placed. In 0·9 per cent. sodium chloride solution, which is isotonic with human blood-plasma, they are unaltered in shape. In hypotonic solutions they swell up, become globular, and finally rupture, owing to the passage of water from the surrounding medium into the corpuscle (*endosmosis*). In hypertonic solutions, e.g. 2 per cent. sodium chloride, water passes in the reverse direction (*exosmosis*) and the corpuscle shrinks and becomes crenated in appearance (fig. 37, *d*). The surface layer of the erythrocyte thus behaves as a membrane which is permeable to water, but not to salts (semi-permeable membrane), and, for this and other reasons, Sharpey-Schafer believes that each corpuscle consists of an envelope containing the

coloured substance, hæmoglobin. According to another view, the erythrocyte consists of a stroma or sponge-work permeated by the hæmoglobin. The stroma or envelope consists mainly of cholesterol, lecithin, and nucleo-protein.

The **colourless corpuscles** or *leucocytes* are of various sizes. In human blood the majority are rather larger than the red corpuscles, and measure about 10μ in diameter. On the average from 7,000 to 12,000 leucocytes are found in each cubic millimetre of blood.

They consist of minute nucleated masses of protoplasm, and exhibit several varieties, which are differentiated from each other chiefly by the occurrence or non-occurrence of granules in their protoplasm, and by the staining reactions of these granules when present (fig. 38). (1) The most numerous and important are termed *polymorphonuclear* leucocytes; they are possessed of the power of amœboid movement, and contain nuclei which often consist of two or three

FIG. 38.—Varieties of colourless corpuscles found in human blood, stained with Leishman's stain. ×1500.



a. Eosinophil corpuscles. *b*. Polymorphonuclear leucocytes. *c*. Hyaline cell or macrocyte. *d*. Lymphocytes.

parts (multipartite) connected together by fine threads of chromatin. It is probable that the character of the nucleus is associated with the remarkable alterations in shape and form which these cells are capable of undergoing in the living condition. When at rest or dead, they are spherical in shape as a rule. The protoplasm contains a number of very fine granules, some of which stain with acid dyes, others with neutral dyes, and are therefore called *oxyphil* or *neutrophil* respectively. They constitute 60 to 70 per cent. of the total number of the colourless corpuscles. (2) A second variety comprises from 1 to 4 per cent. of the leucocytes; they are larger than the previous kind, and are made up of coarsely granular protoplasm, the granules being highly refractile and grouped round single nuclei of horseshoe shape. The granules stain deeply with eosin, and the cells are therefore often termed *eosinophil* corpuscles. (3) A third variety is called the *hyaline* cell or *macrocyte*. This is usually about the same size as the eosinophil cell, and, when at rest, is spherical in shape and contains a single round or oval nucleus. The protoplasm is free from granules, but is not quite transparent, having the appearance of ground glass. (4) A fourth kind is designated the *lymphocyte*, because it is identical with the cells derived from the lymph-glands, or other lymphoid tissue. They are the smallest of the leucocytes, and each consists of a spheroidal nucleus surrounded by a small quantity of homogeneous protoplasm. The third and fourth varieties together constitute from 20 to 30 per cent. of the colourless corpuscles, but of the two varieties the lymphocytes are by far the more numerous. Leucocytes having in their protoplasm granules which stain with basic dyes (*basiphil*) have been described as occurring in human blood, but they are rarely found except in disease.

The colourless corpuscles are very variable in shape in living blood, because many of them have the power of changing their form by protruding finger-shaped or filamentous processes of their substance, by which they move and take up granules from the surrounding medium. In locomotion the corpuscle pushes out a process of its substance—a *pseudopodium*, as it is called—and

gradually the rest of the body flows into it. In the same way when any granule or particle comes in its way the corpuscle protrudes a pseudopodium towards it, and then draws the particle into its own substance. By means of these amœboid properties the cells have the power of wandering or emigrating from the blood-capillaries by penetrating between the cells which form their walls and thus finding their way into the extravascular spaces. The solid chemical constituents of leucocytes are nucleo-protein, globulin, fat, cholesterol, lecithin, glycogen, and salts.

The **blood-platelets** (fig. 39) are oval, colourless, refractile discs, varying somewhat in size but with an average measurement of 3μ in their longest diameter and numbering between 200,000 and 300,000 per cubic millimetre. They are possessed of no demonstrable nucleus or chromatin material, but consist of a homogeneous cytoplasm in which are imbedded a number of highly refractile granules. These granules are usually grouped centrally, and in fixed preparations they may be so closely packed as to present the appearance of a more or less homogeneous mass, closely simulating a nucleus. In shed blood these elements rapidly disintegrate with the liberation of thrombokinase, and in ordinary blood smears they are frequently so grossly changed as to render observations on their morphology in such preparations of little value. They are best studied in blood which has been drawn directly into an anticoagulant, Toisson's solution (without any stain) preserving their form better perhaps than solutions of citrate or oxalate. They stain readily, but not deeply, with the various basic dyes such as neutral red, methylene blue, brilliant cresyl blue, etc., and in fixed preparations stained with one of the Romanowsky stains (Giemsa, Leishman) the cytoplasm appears a pale blue and the granules imbedded in it a reddish purple. These granules are spoken of as the azurophil granules and are similar in staining properties to those seen in the large mononuclear leucocytes. Recent work has shown that the platelet is undoubtedly an independent formed element of the blood, which does not have its origin either in the disintegration of leucocytes or red corpuscles or the precipitation of one of the proteins present in the plasma. The question of their origin awaits a definite solution, though in the opinion of the majority of hæmatologists they arise from the megakaryocytes or giant cells of the hæmopoietic tissue.

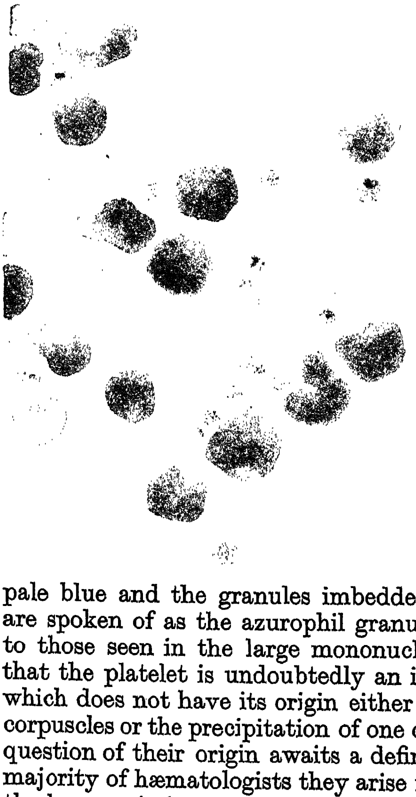


FIG. 39.—Blood-platelets. Highly magnified. (Blood-platelets in blue, red blood cells in pink.) From a preparation supplied by S. Phillips-Bedson of the Lister Institute, London.

Although the functions of the blood-platelet are as yet imperfectly understood, it is generally accepted that they play an important rôle in the process of coagulation. When blood is shed and comes in contact with a foreign and wetable surface, these elements rapidly disintegrate, with the liberation of some substance essential to thrombin formation. This substance has been termed thrombokinase or cytozyme, and although its existence is not generally accepted it can be shown that in the test-tube the coagulation rate of oxalate plasma on the addition of graduated amounts of calcium can be greatly accelerated by the simultaneous addition of platelets or platelet extract, and further, this activity is definitely and specifically neutralised by an anti-platelet serum. In addition to this the presence of platelets is necessary for the retraction which the blood-clot normally undergoes, and it would seem that these elements are essential to the formation of a firm thrombus. A clot formed of fibrin alone, or poor in platelets, is easily dislodged from the wound which it is plugging, but when it is admixed with platelets a much firmer structure results, which, in contracting, knits together to some extent the edges of the wound. It has further been

shown from animal experiments with anti-platelet serum and from observations on purpura in man that a grave destruction of platelets in the circulation is accompanied by extreme capillary bleeding. Recently an attempt has been made to demonstrate that the platelet plays some part in the mechanism of defence against infection. When micro-organisms are introduced into the blood stream the platelets clump round them, forming little masses in which the bacteria are entangled. These masses are held up in the capillaries and the back-waters of the circulation, and are there dealt with by the various phagocytic cells. The same thing occurs if a suspension of inert particles such as Indian ink is introduced into the blood stream; it is the foreign surface which is the exciting cause of this phenomenon.

The development of the blood-corpuscles is described on pp. 132, 133.

The **lymph** is a transparent, colourless or slightly yellow fluid, which is conveyed into the blood by a set of vessels named *lymphatics*. These vessels arise in nearly all parts of the body as *lymph-capillaries*. They take up the fluid which has exuded from the blood-capillaries for the nourishment of the tissues, and return it into the veins through the medium of the thoracic duct or right lymphatic duct.

Lymph is a watery fluid of sp. gr. about 1·015; it closely resembles the blood-plasma, but is more dilute. When it is examined under the microscope, leucocytes of the lymphocyte class are found floating in the transparent fluid; they are always increased in number after the passage of the lymph through lymphoid tissue, as in lymph-glands.

The Reticulo-Endothelial System.

Although they are not usually classified as one of the tissues of the body, the cells which comprise the reticulo-endothelial system may, conveniently, be mentioned at this stage. They form a loose reticulum lying in close relationship to endothelial spaces such as occur in the spleen pulp and bone-marrow, hence the name of the system. The cells, which are highly phagocytic, are found in certain definite situations in the body. When necessity arises, they are able to free themselves from the tissue they help to form, and acquire motility which is amœboid in character.

In the resting condition the cells of the reticulo-endothelial system are found in the following situations: (1) the connective tissues, where they have already been described as clasmatocytes (p. 8); (2) the blood, where they occur as large mononuclear leucocytes; (3) the endothelium lining the vascular sinuses in bone-marrow, the spleen, the liver—where they are termed Kuppfer's cells—the lymph glands, the medulla of the suprarenal gland and the anterior lobe of the hypophysis cerebri; (4) in the retiform tissue of the spleen and the lymph glands, where they can be identified as reticular cells; and (5) in the meninges, where they are termed meningocytes. It has been found experimentally that these cells, and only these cells, will take up such colloidal dyes as trypan blue when they are introduced into the body, subcutaneously, intramuscularly, intravenously or intraperitoneally in dilute solutions. *In situ* they are capable of absorbing hæmoglobin and converting it into bilirubin, and they can take up and store cholesterol.

Although they can be identified as apparently fixed cells in the situations cited, they retain the power of transforming themselves into motile phagocytes when necessity arises. Under these circumstances they become considerably enlarged and have been termed macrophages.* In this condition they migrate from their original position to any point in the body where their phagocytic activity is called for by the presence of foreign substances of various kinds.

It will be observed that no definition of the system is possible, unless the physiological characters of the cells are taken into consideration, for their similarity in function is the only feature which these cells have in common.

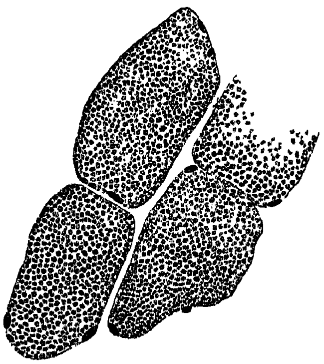
There is some ground for believing that macrophages may become transformed finally into inert fibroblasts, as the last and final stage in their development.

* The term 'histiocytes' is frequently used with approximately the same significance.

MUSCULAR TISSUE

Muscular tissue is composed of bundles of reddish fibres endowed with the property of contractility. There are three varieties of muscle, (1) *striped* or *voluntary*, (2) *unstriped* or *involuntary*, and (3) *cardiac*. The muscles which are concerned with the movements of the bony skeleton—the skeletal muscles—are composed of striped fibres, and are under the control of the will. The muscular coats of the stomach and intestines, uterus, bladder and blood-vessels, on the other hand, are formed of unstriped fibres, and their movements are involuntary. Some striped muscles, however, are not under voluntary control, namely, those forming the walls of the pharynx and upper part of the œsophagus. Cardiac muscle is intermediate in position between the other two varieties. Its fibres are striped, but involuntary, and they differ from both striped and unstriped muscle in structure. With the exception of the arrectores pilorum and the sphincter and dilatator pupillæ muscles, which are derived from the ectoderm, all muscle tissue is mesodermal in origin.

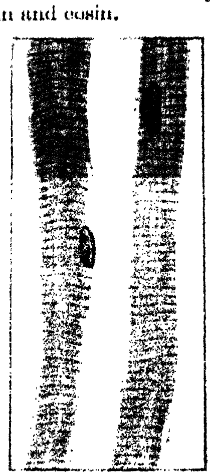
FIG. 40.—A transverse section through human striped muscle-fibres. ×255.



The striped muscular fibres are arranged in bundles or *fasciculi*, in which the individual fibres are parallel to one another. Each fasciculus has a connective tissue sheath, called the *perimysium*, prolongations of which run into the bundle, binding the fibres together and constituting the *endomysium*. A muscle is composed of a number of fasciculi, held together and surrounded by connective tissue which is known as the *epimysium*. The fasciculi are of different sizes in different muscles, and are for the most part placed parallel with one another, though they usually converge towards the tendinous attachments. The connective tissue framework of the muscle contains the blood-vessels and nerves which supply it.

A *muscular fibre* consists of a soft contractile substance, enclosed in a tubular sheath called the *sarcolemma*. The fibres are cylindrical or prismatic in shape (fig. 40), and are of no great length, not exceeding as a rule 40 mm. Their breadth varies in man from 0·01 mm. to 0·1 mm. As a rule, the fibres do not divide or anastomose; but occasionally, especially in the tongue and facial muscles, they may be seen to divide into several branches. In the substance of the muscle the fibres end by tapering extremities which are joined to the ends of other fibres by the sarcolemma. Where a muscle joins its tendon, the sarcolemma covering the end of each muscle-fibre blends with a corresponding group of the fine fibres of the tendon. The muscular substance of the fibre can readily be made to retract from the point of junction. The areolar tissue between the fibres is prolonged into the tendon, so as to form a kind of sheath around the tendon-bundles for a longer or shorter distance. When muscular fibres are attached to skin or mucous membranes, this sheath becomes continuous with the areolar tissue of these structures.

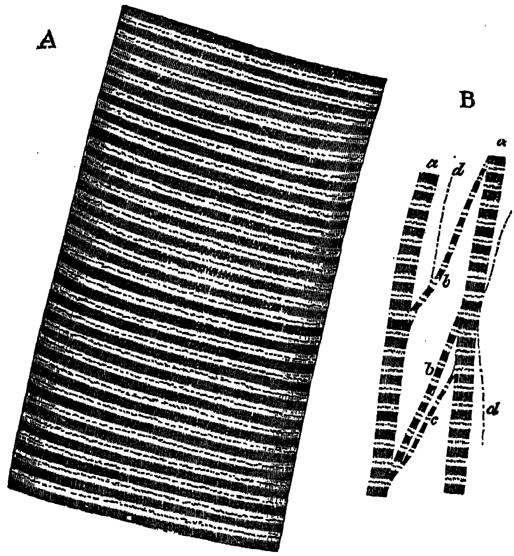
FIG. 41.—Striped muscle fibres (human) from the sternothyroid muscle, stained with hæmatoxylin and eosin.



The *sarcolemma*, or tubular sheath of the fibre, is a transparent, elastic, and apparently homogeneous membrane of considerable toughness, so that it sometimes remains intact when the included substance is ruptured. On the internal surface of the sarcolemma in mammalia, and also in the substance of the fibre in frogs, elongated nuclei are seen, and each of these is surrounded by a little granular protoplasm.

Upon examination of a voluntary muscular fibre by transmitted light, it is found to be marked by alternate light and dark bands or striæ, which pass transversely across the fibre (fig. 41). When examined by polarised light the dark bands are found to be doubly refracting (anisotropic), while the clear stripes are singly refracting (isotropic). The dark and light bands are of nearly equal breadth, and alternate with great regularity; they vary in breadth from about 1μ to 2μ. When the fibre is focussed deeply a dark line may be seen running in the middle of the clear stripe. This is known as *Dobie's line* or *Krause's membrane*. In fibres which are on the stretch the dim stripe is often seen to be divided by a clearer line—*Hensen's line.*

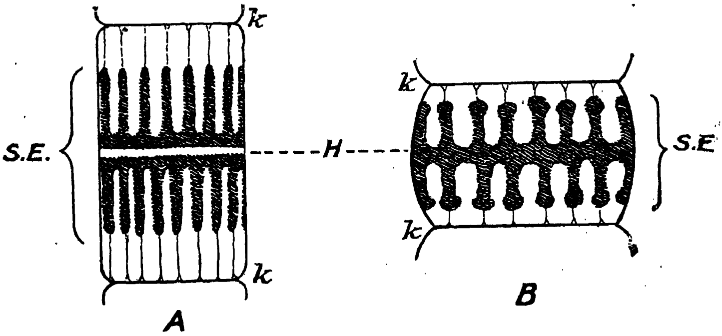
Fig. 42.—A. A portion of a medium-sized human muscular fibre. Magnified nearly 800 diameters. B. Separated bundles of fibrils, equally magnified. (From Quain's Elements of Anatomy.)



a, a. Larger, and *b, b,* smaller collections. *c.* Still smaller. *d, d.* The smallest which could be detached.

Under high magnification there are indications that the striped muscle-fibre is made up of a large number of fibrils, known as *sarcostyles,* together with an interfibrillar material, or *sarcoplasm* (fig. 42, B). When a fibre is treated with weak acid it becomes clearer, and the sarcoplasm is visible as fine, longitudinal, parallel lines. At the junction of the dim and clear stripes these lines often show bead-like enlargements in the stretched condition of the fibre. Examination of transverse sections of individual fibres shows that each sarcostyle is surrounded by sarcoplasm, and that the sarcostyles are arranged in groups, called *muscle-columns,* the groups being separated by a relatively larger amount of sarcoplasm than the separate fibrils. The sections of muscle-columns, defined in this way, constitute what are known as *Cohnheim's areas.*

Fig. 43.—A diagram of a sarcomere. (After Sharpey-Schafer.) A. In a moderately extended condition. B. In a contracted condition.



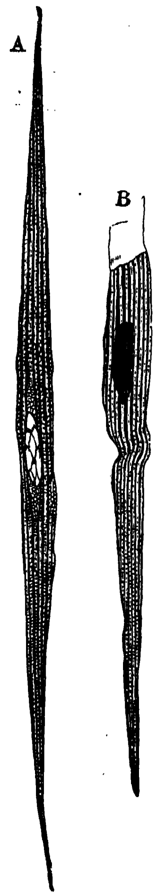
H. Line of Hensen. *k, k.* Membranes of Krause. S.E. Sarcous element.

When the sarcostyles are separated by suitable methods it becomes evident that each exhibits alternate dim and clear portions, with Dobie's and Hensen's lines, and that the striped appearance of the fibre is due to the apposition of the corresponding segments of the fibrils of which it is composed.

Sir E. Sharpey-Schafer worked out the minute anatomy of muscular fibres, particularly in the wing-muscles of insects, which are peculiarly adapted for this purpose on account of the relatively large size of the sarcostyles and the ease with which they can be separated, and the description given below is based on his work.

A sarcostyle may be said to be made up of successive portions, each of which is termed a *sarcomere*. The sarcomere is situated between two membranes of Krause, and consists of (1) a central dark part, which forms a portion of the dark band of the whole fibre, and (2) a clear area at either end, each forming, with the corresponding clear part of the adjacent sarcomere, the light band of the fibril. The central dark segment really consists of two parts, and when the fibre is stretched these two parts become separated from each other at the line of Hensen (fig. 43, A). The clear areas are well marked in the extended sarcostyle, but in the contracted sarcostyle they are small or altogether absent (fig. 43, B).

FIG. 44.—Muscle fibres from the small intestine. (From Quain's Elements of Anatomy, vol. ii. pt. i., Microscopic Anatomy, by Sir Edward Sharpey-Schafer.)



A. Complete cell. B. Broken cell showing delicate external layer.

The central dim portion, or *sarcous element*, does not lie free in the sarcomere, for when the sarcostyle is stretched, very fine lines, which are probably septa, may be seen running through the clear portion from the sarcous element to the membrane of Krause.

Sharpey-Schafer explains these phenomena in the following way. He considers that each dim segment contains a number of longitudinal channels, which open into the clear part towards the membrane of Krause but are closed at the line of Hensen. When the muscular fibre contracts the clear part of the muscular substance passes into these channels or tubes, and is therefore hidden from sight, but at the same time it swells up the sarcous element and widens and shortens the sarcomere. When, on the contrary, the fibre is stretched, this clear substance is driven out of the tubes and collects between the sarcous element and the membrane of Krause, and gives the appearance of the light part between these two structures; by this means it elongates and narrows the sarcomere.

Sharpey-Schafer has shown that, if this view be correct, it harmonises the contraction of muscle with the amœboid action of protoplasm. In an amœboid cell there is, according to one view of the structure of protoplasm, a framework of spongioplasm, enclosing in its meshes a clear substance, termed hyaloplasm. Under stimulation the hyaloplasm passes into the pores of the spongioplasm; without stimulation it tends to pass out, as in the formation of pseudopodia. In muscle there is the same thing, viz. a framework of spongioplasm—the substance of the dim segment; and this encloses a clear hyaloplasm—the clear substance of the sarcomere. During contraction of the muscle—i.e. under stimulation—this clear substance passes into the pores of the spongioplasm; while during extension of the muscle—i.e. when there is no stimulation—it tends to pass out of the spongioplasm. In this way the contraction is brought about; under stimulation the protoplasmic material (the clear substance of the sarcomere) recedes into the sarcous element, causing the sarcomere to widen out and shorten. The contraction of the muscle is merely the sum total of this widening out and shortening of these bodies.

Vessels and nerves of striped muscle.—The *capillaries* of striped muscle are very abundant, and form a sort of rectangular network, the branches of which run longitudinally in the endomysium between the muscular fibres, and are joined at short intervals by transverse anastomosing branches. In the red muscles of the rabbit dilatations occur on the transverse branches of the capillary network. The larger vascular channels (arteries and veins) are found only in the perimysium, between the muscular fasciculi. *Nerves* are profusely distributed to striped muscle. Their mode of termination is described in the chapter on Neurology. *Lymph vessels* do not occur in striped muscle, though they have been found in tendons and in the sheaths of the muscles.

According to John Irvine Hunter, vertebrate muscle, like that of the invertebrates, consists of two kinds of fibres, i.e. those connected with active contraction, and those responsible for the maintenance of tonic contraction. The former are the ordinary striped muscle fibres innervated by ordinary medullated motor fibres. The latter consist of thin, red fibres, rich in sarcoplasm, and with a non-medullated sympathetic nerve-supply. Though adequate

proof has been adduced for the double innervation of striped muscle, no unequivocal experimental evidence has been advanced in favour of the regulation of muscle-tone by sympathetic nerves.

The **unstriped, plain, or involuntary muscle** is found in the following situations—in the lower half of the œsophagus and the whole of the remainder of the gastro-intestinal tube; in the trachea and bronchi; in the gall-bladder and bile-duct; in the large ducts of the salivary and pancreatic glands; in the calyces of the kidney, the ureter, including its pelvis, the bladder, and urethra; in the female sexual organs—viz. the ovary, the uterine tube, the uterus (enormously developed in pregnancy), the vagina, the broad ligament, and the corpora cavernosa of the clitoris; in the male sexual organs—viz. the dartos of the scrotum, the vas deferens and epididymis, the seminal vesicle, the prostate and the corpora cavernosa and corpus spongiosum of the penis; in the capsule and trabeculæ of the spleen; in the mucous membranes, forming the muscularis mucosæ; in the skin, forming the arrectores pilorum, and also in the sweat-glands; in the mammary glands; in the arteries, veins, and lymph vessels; in the iris and ciliary muscle.

FIG. 45.—Anastomosing muscular fibres of the heart seen in a longitudinal section. On the right the limits of the separate cells with their nuclei are exhibited somewhat diagrammatically. (Schweigger-Seidel.)

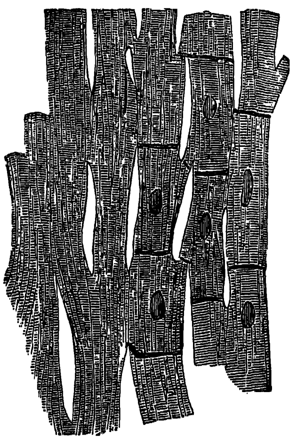


FIG. 46.—Cardiac muscle, stained with hæmatoxylin and eosin. (Human.)

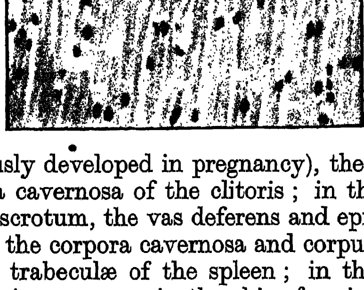
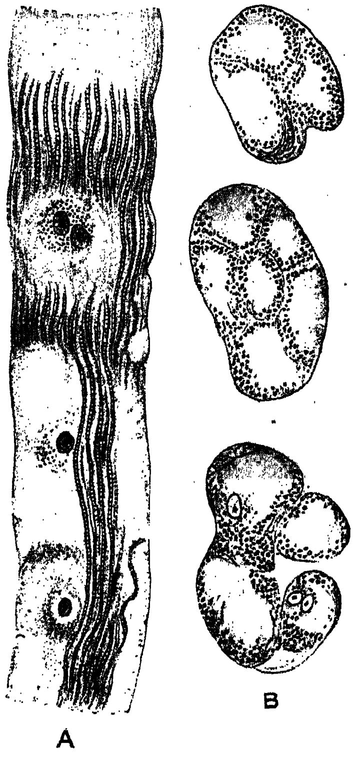


FIG. 47.—Purkinje's fibres from the sheep's heart. × 250.



A. In longitudinal section.
B. In transverse section.

Unstriped or plain muscle is made up of spindle-shaped cells (fig. 44), collected into bundles and held together by a cement-substance. These bundles are further aggregated into larger fasciculi, or sheets, bound together by areolar tissue.

The cells are elongated, spindle-shaped, and nucleated, and are of various sizes, averaging from 40μ to 80μ in length, and 6μ to 7μ in breadth. On trans-

verse section they are more or less polyhedral in shape, from mutual pressure. Each presents a faint longitudinal striation and consists of an elastic cell-wall containing the contractile substance, and an oval or rod-like nucleus. A centriole lies close to the nucleus. The fibres are attached to one another by a certain amount of interstitial cement-substance which reduces nitrate of silver, but in some regions, e.g. the muscular coat of the intestines, the muscle-cells are also connected by ' bridges ' similar to those which occur in the prickle cells of the epidermis.

Sheets of smooth muscle frequently exhibit rhythmical contractions, which are more sluggish than the contractions of striped muscle and in many cases travel along the sheet in the form of waves. Such waves are well marked in the wall of the intestine. Contraction is often excited by a mechanical stimulus; for example, distension of the urinary bladder or of the rectum excites the appropriate reflex of evacuation.

The cardiac muscular tissue.—The fibres of the heart differ very remarkably from those of other striped muscles. They are striated both transversely and longitudinally, but the striation is finer as compared with that of striped muscle. The tissue consists of a branched syncytium in which there is no clear, cellular definition. The apparent cell boundaries (fig. 46) are now generally believed to be due to localised bands of contraction or to fragmentation during preparation of the specimen. The nuclei, which are oval in outline and central in position (fig. 45), occur at regular intervals. The connective tissue between the bundles of fibres is much less than in ordinary striped muscle, and no sarcolemma has been proved to exist.

Purkinje's fibres (fig. 47).—Between the endocardium and the ordinary cardiac muscle peculiar fibres known as *Purkinje's fibres* are found imbedded in a small amount of connective tissue. They are associated with the terminal distributions of the atrioventricular bundle. In man the fibres are no larger in size than the cardiac cells but differ from them in several ways. In longitudinal section they are quadrilateral in shape, being about twice as long as they are broad. The central portion of each fibre contains one or more nuclei and is made up of granular protoplasm, with no indication of striation, while elsewhere in the fibre transverse striations are conspicuous (fig. 691). The fibres are intimately connected with each other, possess no definite sarcolemma, and do not branch. They form a considerable portion of the moderator band in the heart of the sheep.

The **atrioventricular bundle** (see chapter on Angiology) is composed of cells which differ from ordinary cardiac muscle-cells in being more spindle-shaped. They are, moreover, more loosely arranged and have a richer vascular supply than the rest of the cardiac muscle.

Development of muscle-fibres.—Voluntary muscular fibres are developed from the mesoderm, the embryonic cells of which elongate, show multiplication of nuclei, and eventually become striated; the striation is first obvious at the side of the fibre, spreads around the circumference, and ultimately extends to the centre. The nuclei, at first situated centrally, gradually pass out to assume their final position immediately beneath the sarcolemma. In the case of involuntary muscle the mesodermal cell assumes a pointed shape at the extremities and becomes flattened, the nucleus also lengthening out to its permanent rod-like form.

NERVOUS TISSUE

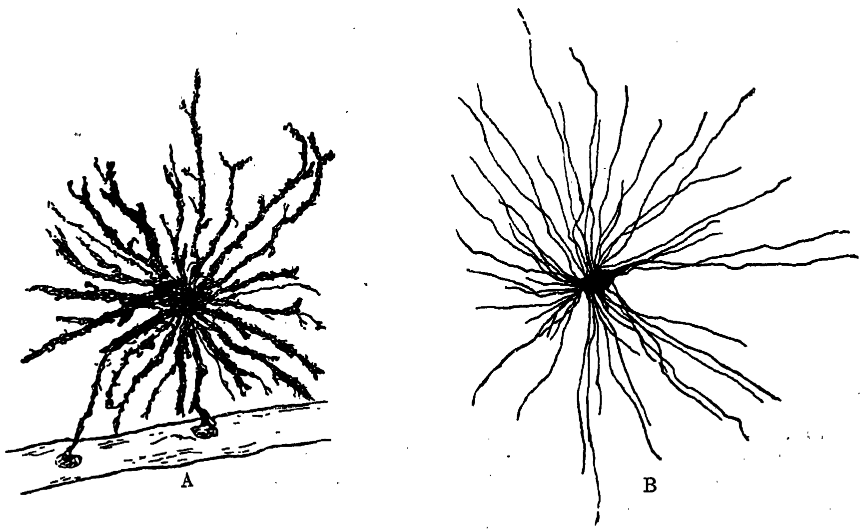
Nervous tissue is specialised for the inauguration, propagation and reception of nerve impulses, and its high degree of specialisation is indicated by the fact that, like muscle tissue, it has lost the power of reproduction. The nervous tissues of the body comprise the brain, the spinal cord, the cranial, spinal, and sympathetic nerves, and the ganglia connected with them.

The nervous tissues are composed of *nerve-cells* and their various processes, together with a supporting tissue called *neuroglia*, which, however, is found only in the brain and spinal cord. Certain long processes of the nerve-cells are of special importance, and it is convenient to consider them apart from the cells; they are known as *axons* or *axis-cylinder processes*, and together with their covering sheaths they form the *nerve-fibres*.

To the naked eye certain portions of the brain and spinal cord appear grey and others white, when freshly cut sections are examined. The *grey matter* is composed largely of nerve-cells, while the *white matter* contains only their long processes, the nerve-fibres. It is in the former that nervous impressions are received, stored, and transformed into efferent impulses, and by the latter that they are conducted. Hence the grey matter forms the essential constituent of all the ganglionic centres, both those in the isolated ganglia and those aggregated in the brain and spinal cord; while the white matter forms the bulk of the commissural portions of the nerve-centres and the peripheral nerves.

Neuroglia is the peculiar variety of ectodermal tissue which binds together the true nervous constituents of the brain and spinal cord. It consists of cells and fibres, and may be regarded as a special variety of connective tissue, found only in association with true nervous tissue. Some of the cells (spider-cells) are stellate in shape, with ill-defined cell-bodies. Their fine processes become neuroglia fibres and extend radially and unbranched (fig. 48 B), among the

FIG. 48.—Neuroglia-cells of the brain shown by Golgi's method. (After Andriezen.) (From Sir E. Sharpey-Schafer's Essentials of Histology.)



A. Arborescent cell with branched processes. B. Spider-cell with unbranched processes.

nerve cells and fibres which they aid in supporting. Other cells (arborescent cells) give off processes which branch repeatedly (fig. 48, A). Some of the fibres start from the epithelial cells lining the ventricles of the brain and central canal of the spinal cord, and pass through the nervous tissue, branching repeatedly, to end in slight enlargements on the pia mater. Thus, neuroglia is evidently a connective tissue in function, but it is not so in development; it is ectodermal in origin, whereas all true connective tissues are mesodermal.

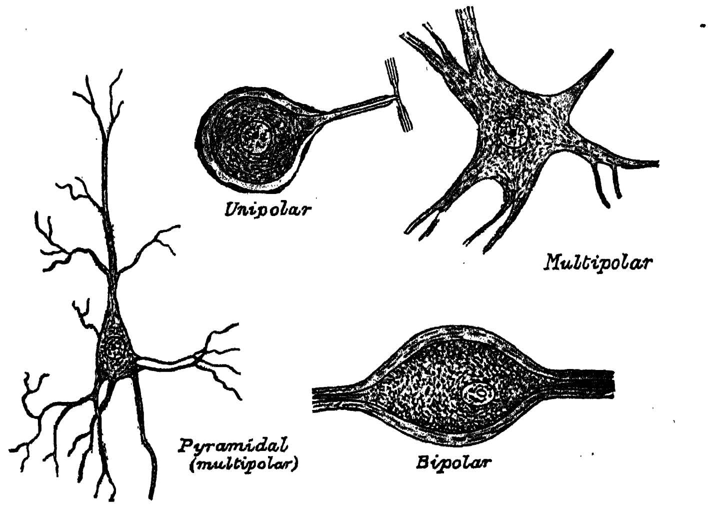
Nerve-cells (fig. 49) are largely aggregated in the grey substance of the brain and spinal cord, but smaller collections of these cells also form the swellings, called *ganglia,* seen on many nerves. These latter are found chiefly upon the spinal and cranial nerve-roots and in connexion with the sympathetic nerves.

Nerve-cells vary in shape and size, and have one or more processes. A typical nerve-cell from the cerebral cortex possesses a number of processes. Of these one, and only one, acts as a transmitter to convey nerve impulses away from the cell. It is termed the *axon* or *axis-cylinder process,* and it has a characteristic structure, to be described later. The other processes are all receptors, and convey nerve impulses to the cell; they are termed *dendrites* and they differ from the axon in structure as well as in other ways. Usually the axon is a long process, which gives off one or two collaterals but does not branch freely until it approaches its termination. The dendrites, on the other hand, are usually short and are restricted to the immediate vicinity of the cell-body. They branch freely, sometimes producing the most intricate patterns

(fig. 52) and end in minute twigs. Such nerve-cells are termed *multipolar*, and they abound in the grey matter of the brain and spinal cord and in the ganglia of the sympathetic system.

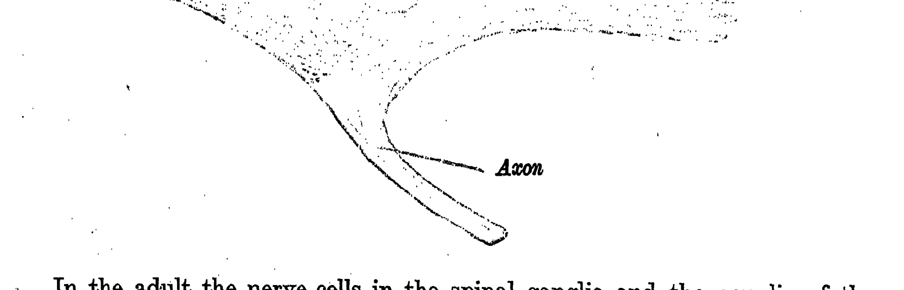
All nerve-cells, however, are not multipolar. The nerve-cells in the retina and in the spiral and vestibular ganglia of the eighth cranial nerve are *bi-polar*

FIG. 49.—Various forms of nerve-cells.



(fig. 49). One process enters the cell from the periphery and functions as a dendrite : the other leaves the cell to enter the brain and functions as the axon. Structurally, however, both are axons. Bipolar cells are found throughout life in the spinal ganglia of fishes, and they occur in the same situation in the human embryo. The condition of bi-polarity therefore may be regarded justifiably as primitive.

FIG. 50.—A motor nerve-cell from the anterior horn of the spinal cord of an ox, stained with methylene blue. × 500. The spindle-shaped Nissl's granules are shown. The dendrites and axon are broken off close to the cell.



In the adult the nerve-cells in the spinal ganglia and the ganglia of the cranial nerves (apart from the eighth) are *unipolar*, and the condition is brought about in the fœtus by the approximation and fusion of the proximal parts of the two processes above-mentioned. The single process of these unipolar cells, after a short course from the cell-body, divides in a T-shaped manner (fig. 49) into two processes. Of these one runs towards the periphery and, as it con-

ducts impulses towards the cell, functions as a dendrite ; the other enters the central nervous system and, as it conducts impulses away from the cell, functions as an axon. Structurally, however, the functional dendrite of a unipolar cell is indistinguishable from the axon.

The body of the nerve-cell is known as the *cyton*. In fixed and stained preparations it consists of a finely fibrillated protoplasmic material in which there are occasionally patches of a deeper tint, caused by the aggregation of

Fig. 51.—A pyramidal cell from the cerebral cortex of a mouse. Golgi method. (After Ramón y Cajal.)

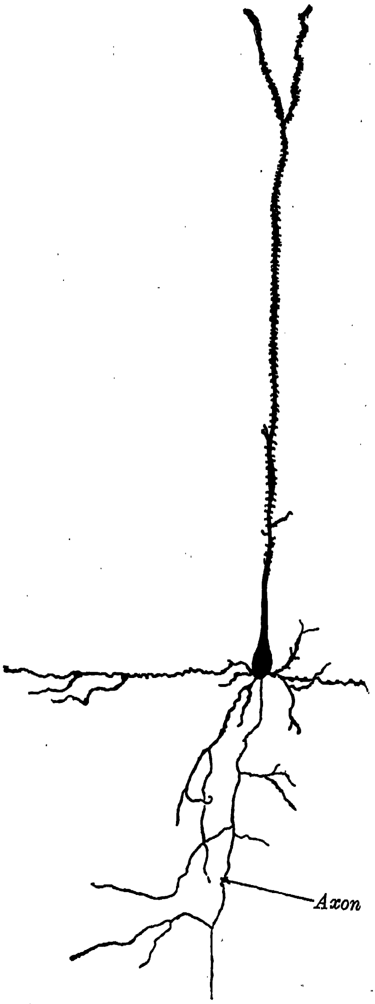
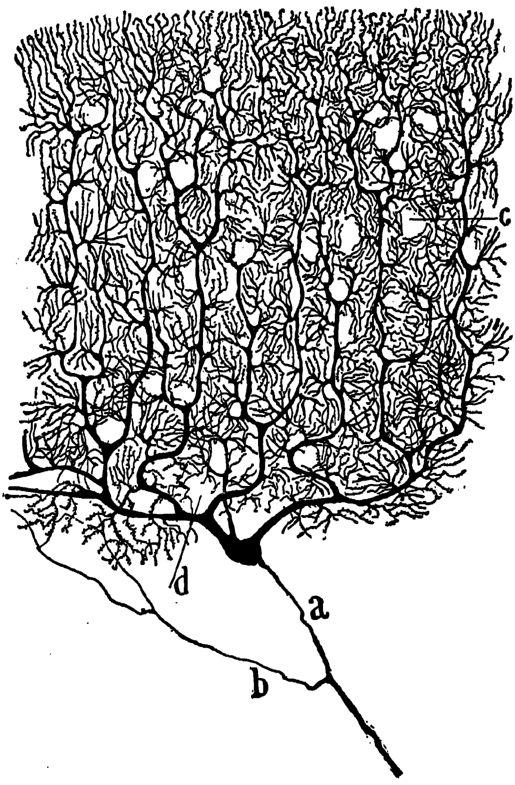


Fig. 52.—A cell of Purkinje from the cerebellum. Golgi method. (Ramón y Cajal.)



a. Axon. *b*. Collateral. *c* and *d*. Dendrites.

pigment-granules at the sides of the nucleus, as in the substantia nigra and locus cœruleus of the brain. The protoplasm also contains peculiar angular masses of granules which stain deeply with basic dyes such as methylene blue ; these are known as *Nissl's spindles* (fig. 50). These bodies extend into the dendritic processes but not into the axon, and they disappear (*chromatolysis*) during fatigue or after section of the nerve-fibre connected with the cell. They are supposed to represent a store of nervous energy, and in various mental diseases are deficient or absent. The nucleus is, as a rule, a large, well-defined body, with a relatively small amount of chromatin, and contains a well-marked nucleolus. The small clear area at the point of exit of the axon is termed the *cone of origin*.

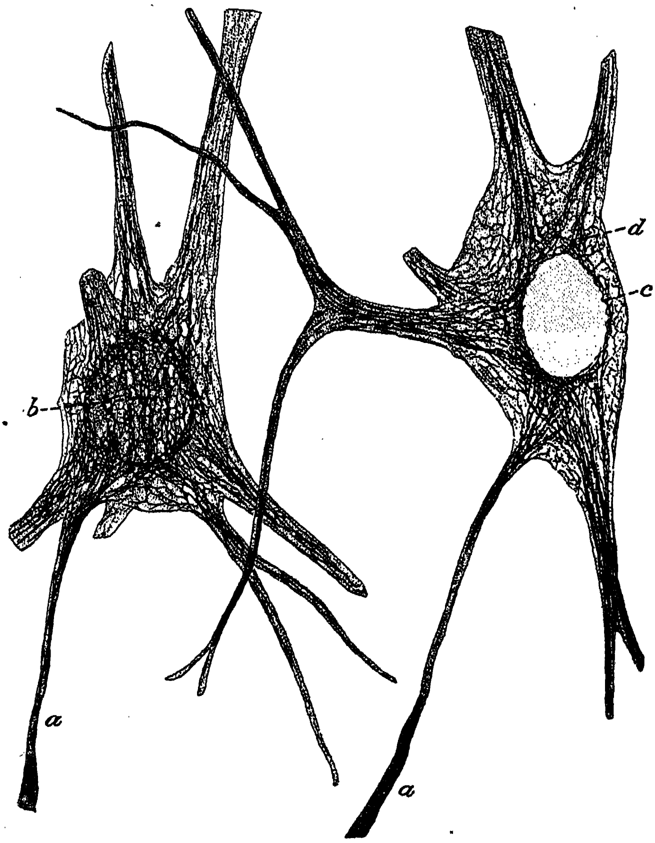
In addition to the protoplasmic network described above, each nerve-cell may be shown to have delicate neurofibrils running through its substance

(fig. 53); these fibrils are continuous with the fibrils of the axon, and are believed to convey nerve-impulses. A *pericellular network* of fine branching fibres is a characteristic feature of many nerve-cells.

Mott and Marinesco have shown that, when living nerve-cells are examined by the dark ground illumination method, neither Nissl's bodies nor fibrils of any kind can be seen. The constancy of the occurrence of both these structures in fixed preparations, however, indicates that they represent something specific in the living cell.

Nerve-fibres are found universally in the peripheral nerves, and in the white matter of the brain and spinal cord. They are of two kinds—viz. *medullated* or *white* fibres, and *non-medullated* or *grey* fibres.

FIG. 53.—Nerve-cells of a kitten, showing neurofibrils. (Ramón y Cajal.)



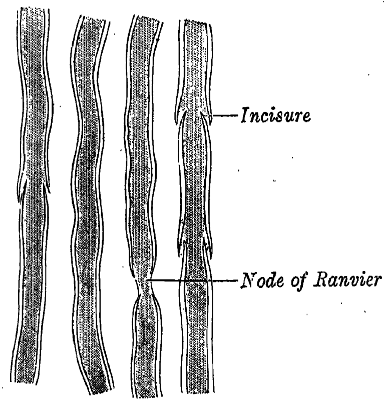
a. Axon. *b.* Cyton. *c.* Nucleus. *d.* Neurofibrils.

The *medullated fibres* form the white matter of the brain and spinal cord, and also the greater part of every cranial and spinal nerve, and give to these structures their opaque, white colour. When perfectly fresh they appear to be homogeneous; but soon after removal from the body each fibre, when examined by transmitted light, presents a double outline or contour, as if consisting of two parts (fig. 54). The central portion is the *axon*; it is surrounded by a sheath of fatty material, staining black with osmic acid, named the *white substance of Schwann* or *medullary sheath*, which gives to the fibre its double contour; and the whole is enclosed in a delicate membrane, termed the *neurolemma, primitive sheath*, or *nucleated sheath of Schwann* (fig. 55). Medullated nerve-fibres vary in dimeter from 2μ to 16μ.

The *axon* is the essential part of the nerve-fibre, and is always present; the medullary sheath and the neurolemma are occasionally absent, especially at the origin and termination of the nerve-fibre. The axon undergoes no interruption from its origin in the nerve-centre to its termination, and must be regarded

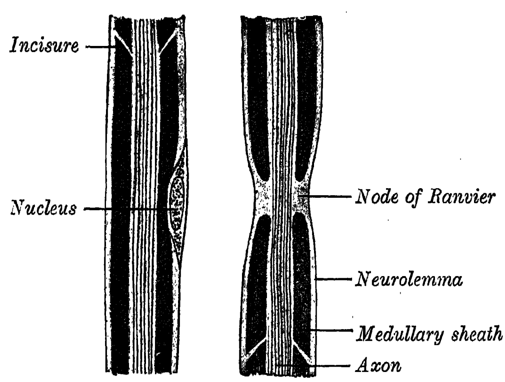
as a direct prolongation of a nerve-cell. Nerve-fibres in the white matter of the brain and spinal cord give off twigs known as *collaterals*. These arise from the main fibre at right angles to its course and run into the grey matter, where they terminate by arborisation. The axon constitutes about one-half or one-third of the nerve-fibre, being greater in proportion in the fibres of the central nervous system than in those of the peripheral nerves. It is quite transparent, and is therefore indistinguishable in a perfectly fresh and natural state of the nerve. It is made up of exceedingly fine fibrils (figs. 55 and 56), which stain darkly with gold chloride, and at its termination may be seen to break up into these fibrils. The axon is said by some to be enveloped in a special reticular sheath, which separates it from the medullary sheath, and is composed of a substance called *neurokeratin*. The more common opinion is that this network or reticulum is contained in the white substance of Schwann, and by some it is believed to be produced by the action of the reagents employed to show it.

Fig. 54.—Medullated nerve-fibres. × 350.



The *medullary sheath* or *white substance of Schwann* (fig. 55) is regarded as being a fatty material in a fluid state, which insulates and protects, or possibly supplies nutriment to, the essential part of the nerve—the axon. As a general rule its thickness is proportional to the size of the axon, and is such that it

Fig. 55.—A diagram of longitudinal sections of medullated nerve-fibres. Osmic acid.



forms about half of the total area of the cross-section of the fibre. Its continuity is interrupted at intervals of about 1 mm., giving to the fibre the appearance of constriction at these points ; these are known as the *nodes of Ranvier* (figs. 54 and 55). The portion of nerve-fibre between two nodes is called an *internodal segment*. The neurolemma or primitive sheath is not interrupted at the nodes, but passes over them as a continuous membrane. Some observers, however, believe that the neurolemma of one internodal segment is connected with that of the adjacent segment at the node by cement-substance. If the fibre be treated with silver nitrate the reagent penetrates the neurolemma at the nodes, and, on exposure to light, reduction takes place, giving rise to the appearance of black crosses (*Ranvier's crosses*) on the axon. Transverse lines, termed *Fromann's lines* (fig. 57), also may be seen beyond the nodes ; their significance is not understood. In addition to these interruptions, oblique clefts or *incisures* may be seen in the medullary sheath, subdividing it into irregular

portions, which are termed *medullary segments*, or *segments of Lantermann* (figs. 54 and 55) ; there is reason to believe that these clefts are artificially produced in the preparation of the specimens. Medullated nerve-fibres, when examined in the fresh condition, frequently present a beaded or varicose appearance, due to manipulation and pressure, which cause the oily matter to collect into drops ; in consequence of the extreme delicacy of the primitive sheath even slight pressure will cause the transudation of the fatty matter, which collects as drops of oil outside the sheath.

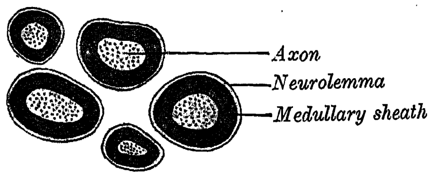


Fig. 56.—Transverse sections through medullated nerve-fibres. Osmic acid.

The *neurolemma* or *primitive sheath* is a delicate, structureless membrane ; here and there beneath it, and situated in depressions in the white substance of Schwann, are nuclei, each surrounded by a small amount of protoplasm. The nuclei are oval and somewhat flattened, and one is generally found in the middle of each internode. *The primitive sheath is absent from the medullated fibres of the brain and spinal cord.*

Wallerian Degeneration.—When nerve-fibres are cut across, the central ends of the fibres degenerate as far as the first node of Ranvier ; but the peripheral ends degenerate simultaneously throughout their whole length. The medullary sheath of each fibre becomes broken down, forming droplets of fatty substance, and the axon undergoes fragmentation. The nuclei of the primitive sheath proliferate, and finally absorption of the axons and fatty substance occurs. If the cut ends of the nerve be sutured together,

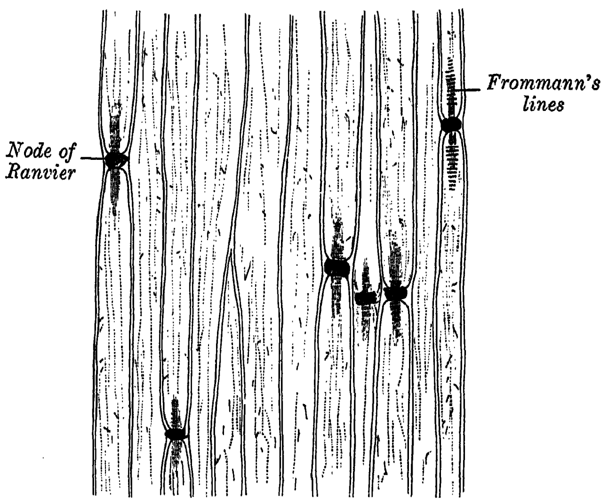


Fig. 57.—Medullated nerve-fibres stained with silver nitrate.

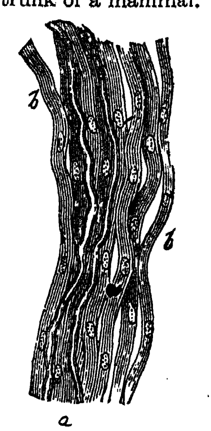


Fig. 58.—A small branch from the sympathetic trunk of a mammal.

a. Two small medullated nerve-fibres among a number of non-medullated nerve-fibres, *b*.

regeneration of the nerve-fibres takes place by the downgrowth of axons from the central end of the nerve. At one time it was believed that the regeneration was peripheral in origin, but this has been disproved, the proliferated nuclei in the peripheral portions taking part merely in the formation of the so-called scaffolding along which the new axons pass. Regeneration of the peripheral end of a cut nerve-fibre occurs only when the fibre possesses a primitive sheath. As a result the medullated fibres of the brain and spinal cord cannot regenerate after they have been severed.

Non-medullated fibres.—Most of the fibres of the sympathetic system, and some of the cerebrospinal, consist of the *grey* or *gelatinous* nerve-fibres—*fibres of Remak* (fig. 58). Each of these consists of an axon to which nuclei are applied at intervals. These nuclei are believed to be in connexion with a delicate sheath corresponding with the neurolemma of the medullated nerve-fibre. In external appearance the non-medullated nerve-fibres are semitransparent and grey or yellowish-grey. The individual fibres vary in size, generally averaging about half the size of the medullated fibres.

EMBRYOLOGY

INTRODUCTION

THE series of changes which constitutes the development of the human body commences when the female germ-cell, or ovum, is fertilised by a male germ-cell, or spermatozoön, and terminates when the adult condition is reached. Embryology deals with the changes which occur prior to the birth of the child.

Two processes, intimately associated with each other although essentially distinct, are responsible for the transformation of the single-celled ovum into the complex form of the newly born child. These processes are (1) *growth* and (2) *differentiation*. Growth, with certain exceptions to be noted later, involves increase in size brought about by cell division and is dependent on the ingestion of a sufficient quantity of the appropriate type of nourishment. The process of growth is not a simple one, for in certain situations it must be accompanied by a process of absorption, which is just as much an indication of growth activity as increase of size. For example, as the mandible increases in size, the anterior part of its ramus is constantly being remodelled by a process of absorption, while the opposite phenomenon of bone deposition is occurring along its posterior border.

Differentiation is the process whereby a group of cells assumes certain special characteristics which enable them to carry out some particular function. It was long believed that all the stimuli which lead groups of cells to undergo differentiation were inherent in the cells themselves and were directly due to an hereditary factor, but this view requires considerable modification in the light of recent experimental work. The earliest cells derived from the fertilised ovum are totipotent, i.e. any one of them may go on to form a complete embryo, but, as development proceeds and the first signs of differentiation appear, the potency of the cells concerned in the differentiation becomes reduced and limited. Before a group of cells can become differentiated along certain lines, it must not only possess the requisite potency but it must also receive a determining stimulus, and this stimulus is usually provided by its environment. Recent experimental work has shown that, so long as their differentiation has not been carried too far, cells which normally give rise to a particular tissue or organ can be influenced to differentiate into quite different structures if they are brought into a different environment, e.g. contact with a group of cells to which they bear no relation normally. Under normal conditions the ectoderm on the surface of the head which overlies the developing optic vesicle undergoes a series of changes and gives rise to the lens. If the optic vesicle is transplanted into the tissues of the abdominal wall, the lens fails to develop in its normal situation, but the ectoderm under which the transplanted vesicle lies will form a lens in the ordinary way. Spemann, working on amphibian larvæ, transplanted portions of the dorsal lip of the blastopore into an undifferentiated region of another embryo. As a result the transplant and the tissues of the host interacted on one another in such a way that a secondary, incomplete embryo formed in the tissues of the host. This, and other experiments of a similar nature, demonstrate the latent potencies of undifferentiated cells and the organising power of the cells situated in the dorsal lip of the blastopore.

Many tissues of the adult body retain their potencies to a large extent and are capable of taking on new characters when an appropriate stimulus is received, always provided that their cells are still able to reproduce themselves. Such processes frequently occur in the formation of tumours and in other pathological conditions. They serve to demonstrate that the individual cells do not possess any inherent tendency to take on special characters but that their future depends on their potencies and their environment.

Differentiation is the result of the activities of certain *growth organisers*, such as the dorsal lip of the blastopore, but it would appear that the latter are unable to control the growth after a certain stage has been reached. For example, a portion of an optic vesicle, if transplanted, may continue to grow

and may give rise to a complete vesicle, independently of the environment in which it may be placed. If it fails to behave in this way, the transplant dies and is absorbed. The regulation and control of the extent of growth processes are apparently effected by the hormones secreted by the ductless glands, but nothing is known of the way in which they exercise their influence.

The importance of embryology.—To the student of medicine the study of human embryology is of great practical value, for it renders intelligible many of the facts of human anatomy which are otherwise meaningless or anomalous. In its early stages the body of the embryo exhibits an almost perfect symmetry, which, owing to a variety of causes, becomes considerably obscured in certain regions of the body in the adult. The normal processes of development supply not only the reasons for these differences but also the explanations of those departures from the normal which constitute congenital abnormalities or defects.

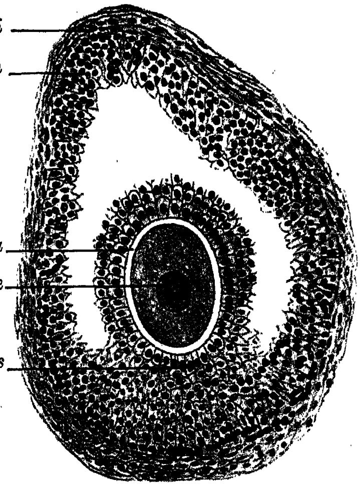
In addition to its value as an aid to the interpretation of human anatomy, embryology possesses importance on account of the evidence which it provides regarding the phylogeny of man. The changes which any embryo undergoes in the course of its development repeat—often, it is true, in a very abridged form—the changes which occurred in the embryos of its ancestral forms. The embryos of all vertebrates exhibit a stage in which gill-arches and clefts are present in the neck region. In fishes the cleft membranes break down and the gills develop and persist as essential functional structures in the adult form. In all air breathing vertebrates this stage, although transient, nevertheless occurs, but, in the human embryo, the cleft membranes never break down. In many cases the constituent parts of the arches become modified and adapted for new uses, a remarkable and noteworthy fact to which reference will be made repeatedly in the following pages.

Having regard to the main purpose of this work, it is impossible, in the space available in this chapter, to describe or illustrate fully all the changes which occur during the development of the human body. Only the principal facts are given, and the student is referred for further details to one or other of the text-books * on embryology.

THE OVUM

The ova develop in the ovary, which is the sexual gland of the female. The primitive sex cells are differentiated at a very early stage of development (p. 192) and by their repeated division give rise to a number of smaller cells, termed *oögonia*. After a time the oögonium ceases to divide and passes through a resting phase. It has now become an *ovum* or *primary oöcyte*, and the changes which it subsequently undergoes constitute the maturation or ripening of the ovum.

Fig. 59.—A section through an ovarian follicle of a cat. ×50.



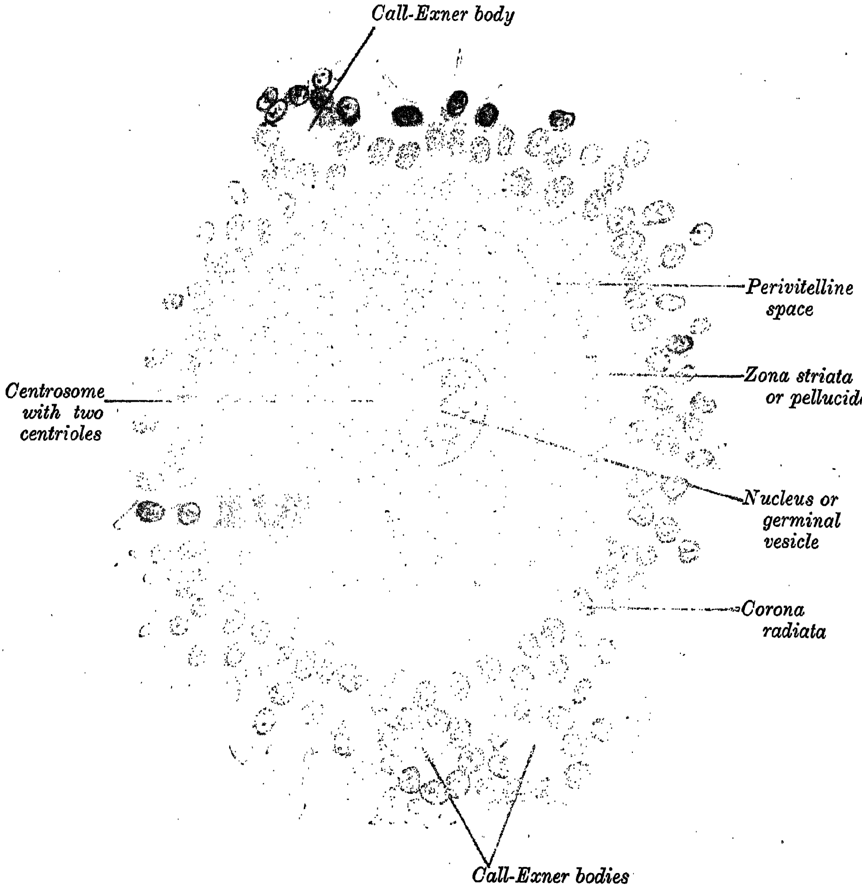
Human ova vary from about 117μ† to 142μ in diameter, according to their stage of development. They are contained within the vesicular (Graafian) follicles of the ovaries; as a rule each follicle contains one ovum, but sometimes two

* *Manual of Human Embryology*, Keibel and Mall; *Handbuch der vergleichenden und experimentellen Entwickelungslehre der Wirbeltiere*, Oskar Hertwig; *Human Embryology and Morphology*, Arthur Keith, 1921; *Traité d'Embryologie des vertébrés*, A. Brachet, 1921; *Vertebrate Embryology*, Jenkinson; *The Physiology of Reproduction*, Marshall; *Manual of Embryology*, J. E. Frazer, 1931.

† μ = ·001 mm.

or more are present. Each ovum is at first invested by a single layer of cubical cells, which by multiplication form several layers. At a later stage a cavity filled with fluid appears amongst the cells, and gradually splits them into two strata, an inner (cumulus ovaricus) and an outer (stratum granulosum); but at one spot the strata remain in continuity. The stratum granulosum is enveloped by a sheath (theca folliculi) derived from the stroma of the ovary * (fig. 59). By the enlargement and subsequent rupture of a follicle at the surface of the ovary, an ovum, surrounded by the cells of the cumulus, is liberated and enters the uterine tube, through which it is conveyed to the cavity of the uterus. Unless the ovum is fertilised it is discharged from the uterus, but if

FIG. 60.—A human ovum stained with Mallory's aniline blue. ×600. Drawn from a specimen lent by Professor Arthur Thomson, University of Oxford.



fertilisation takes place it is retained there and is developed into a child, which is born at the end of ten lunar months of twenty-eight days or nine calendar months.

Although the ovum (fig. 60) is very much larger than the ordinary cell, it resembles it closely in structure and general appearance, but distinctive names are given to its several parts; thus, the cell-substance is known as the *yolk* or *oöplasm*, the nucleus as the *germinal vesicle*, and the nucleolus as the *germinal spot*. The ovum has a thick, transparent envelope named the *zona striata* or *zona pellucida*, and then the ovum is liberated from the vesicular follicle, several layers of cells, derived from those of the cumulus ovaricus, adhere to the outer surface of the zona pellucida, and collectively constitute the *corona radiata*.

It should be stated that a radical selective elimination occurs in human ova during the late stages of the growth of the follicles. Only one ovum is shed from each ovary in each menstrual cycle, but in the same period a large number

* For further particulars, see description of the ovary under Splanchnology.

(5-20), although developing normally for a time, subsequently show atretic changes and become degenerated.*

The **yolk** comprises (1) *cytoplasm* similar to that of the ordinary animal cell (p. 1), and frequently termed the *formative yolk*; (2) *deutoplasm* or *nutritive yolk*, which consists of fatty droplets containing lecithin—a phospholipin closely allied to and found with the animal fats.† In the mammalian ovum the deutoplasm is extremely small in amount, and nourishes the embryo in the early stages of its development only, whereas in the egg of the bird there is sufficient to supply the chick with nutriment throughout the whole period of incubation. The mode of distribution of the deutoplasm within the egg varies in different animals; in some it is almost uniformly dispersed throughout the cytoplasm; in others it is centrally placed and surrounded by the cytoplasm; and in others it is accumulated at the lower pole of the ovum, while the cytoplasm occupies the upper pole. A *centrosome* and *centrioles* are sometimes present and lie in the immediate neighbourhood of the nucleus; they are absent, however, in the mature ovum (p. 47).

The **nucleus** or **germinal vesicle** is a large spherical body which usually occupies an eccentric position in the yolk. Its structure is that of an ordinary cell-nucleus, viz. it consists of a reticulum or karyomitome the meshes of which are filled with karyoplasm. Connected with, or imbedded in, the reticulum there are a number of chromatin masses or chromosomes, which may present the appearance of a skein or may assume the form of rods or loops. The nucleus is enclosed by a delicate nuclear membrane, and contains in its interior a well-defined nucleolus or germinal spot.

THE COVERINGS OF THE OVUM

The **zona pellucida** or **zona striata** (fig. 60) is a thick membrane, which, under the higher powers of the microscope, is seen to be radially striated. Between it and the cytoplasm of the ovum there is a narrow *perivitelline space*, filled with fluid, in which the polar bodies are seen lying after their extrusion from the ovum. Thomson ‡ describes the zona pellucida as consisting of (*a*) an inner, homogeneous layer which is derived from the ovum, and (*b*) an outer, fibrillar layer formed by the felting of the basal fibres of the innermost cells of the corona radiata. He is also of opinion that there is distinct evidence of a *vitelline membrane* within the zona pellucida.

The **corona radiata** (fig. 60) consists of two or three strata of radially arranged cells. These consist of the cells of the cumulus ovaricus, which adhere to the outer surface of the zona pellucida when the ovum is set free from the vesicular follicle. The cells of the innermost layer are columnar in shape, and send delicate processes through the zona pellucida, thus giving the latter a striated appearance.

THE MATURATION OF THE OVUM

Before an ovum or primary oöcyte can be fertilised, it must undergo a process of *maturation* or *ripening*. This consists of a preliminary stage of growth during which the ovum increases greatly in size, followed first by a heterotypical or reduction division and then by a homotypical division. The whole process has been carefully studied in the ova of many of the lower animals and the following description is based on these investigations.

During the stage of growth, changes occur both in the nucleus and in the cytoplasm. The nuclear changes affect chiefly its chromatin content. The chromosomes become prominent and stain deeply with basic dyes. They unite with one another in pairs, usually in their long axes, so that their number is reduced by half, each however representing a double chromosome. This process is termed the *conjugation of the chromosomes*, and it would appear to be

* Edgar Allen, J. P. Pratt, Q. U. Newell and L. J. Bland, *American Journal of Anatomy*, vol. 46, No. 1.

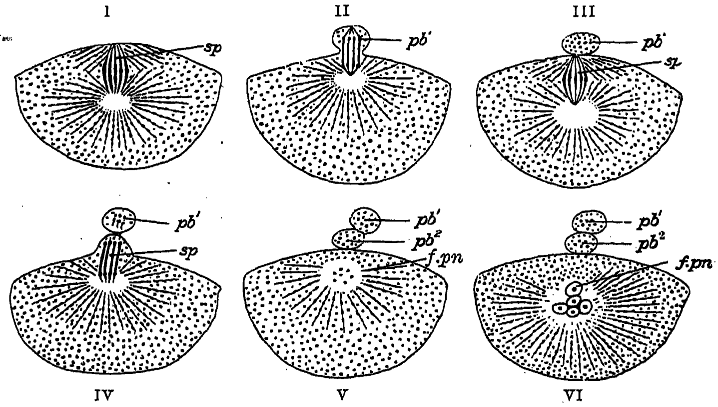
† Arthur Robinson (*Proceedings of the Anatomical Society of Great Britain and Ireland*, 1925, p. 109) has shown that unsaturated fat, demonstrable by osmic acid, is practically absent from human ova, and from the ova of rats and mice, but is present in large amount in the ova of dogs and ferrets, where it forms the greater part of the volume of the ova.

‡ Professor Arthur Thomson, *Journal of Anatomy*, vol. liii. 1919.

an essential preliminary to the ensuing heterotypical division. As already stated (p. 2) the number of chromosomes found in the nucleus is constant for all the cells in an animal of any given species, and in man the number is probably forty-eight. This applies not only to the somatic cells but to the oögonia and the primary oöcytes also. In the latter two of the chromosomes are believed to possess distinguishing features and are known as the x-chromosomes. The conjugation process reduces the number of chromosomes in the human primary oöcyte to twenty-four, one of which is formed by the union of the two x-chromosomes with each other.

The changes in the cytoplasm which mark the period of growth result in a great increase in the size of the cell. Its metabolic processes become extremely active, and a store of nourishment is accumulated which is necessary for the supply of the ovum during the early stages of its development. The essential feature of the metabolic activity is the *formation of deutoplasm*, but at the same time the amount of protoplasm increases, and the mitochondria become much more numerous.

FIG. 61.—The formation of the polar bodies in Asterias glacialis. (Slightly modified from Hertwig.)



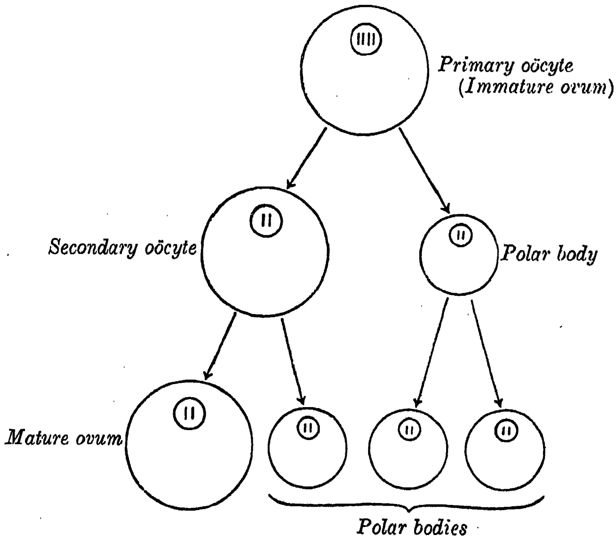
In fig. I the polar spindle (*sp*) has advanced to the surface of the egg. In fig. II a small elevation (pb^1) is formed which receives half of the spindle. In fig. III the elevation is constricted off, forming the first polar body (pb^1), and a second spindle is formed. In fig. IV is seen a second elevation which in fig. V has been constricted off as the second polar body (pb^2). Out of the remainder of the spindle (*f.pn* in fig. VI) the female pronucleus is developed.

Having passed through this period of growth, the ovum is now ready to undergo heterotypical division. Near its upper pole the double chromosomes arrange themselves in an equatorial plate with reference to the spindle, which is placed radially. The chromosomes divide and one half of them pass centrally, while the other half pass outwards, forming a projection at the upper pole of the ovum, which becomes separated off to form the *first polar body*. The division of the cytoplasm, unlike the division of the nucleus, is unequal, and the polar body only carries with it a small part of the cytoplasmic content of the ovum. Following this reductional division the nucleus of the larger cell, which is now a *secondary oöcyte*, is not reconstituted before the cell again divides. Its chromosomes rearrange themselves in an equatorial plate at the upper pole of the cell, and undergo homotypical division so that a *second polar body* is formed. The larger cell, which has lost but little of its cytoplasm, is now a *mature ovum* and lies within the zona pellucida, together with the two polar bodies, or three, if the first has succeeded in dividing, as it does in some species. The chromosomes of the mature ovum lose their identity during the resting stage prior to fertilisation and form a reticulum, constituting the *female pronucleus*. The mature ovum is characterised (1) by the number of its chromosomes, which is just one-half of the typical number for the somatic cells of the species, (2) by its great size and the large amount of cytoplasm relative to the size of the nucleus, and (3) by the presence of the deutoplasm. The sequence of heterotypical and homotypical divisions which is characteristic of the maturation of the sex cells, is termed meiosis.*

* Different authors employ the term 'meiosis' with varying shades of meaning, but it always implies a reduction in the number of chromosomes.

In most vertebrates the heterotypical division occurs before the ovum or primary oöcyte is liberated from the vesicular (Graafian) follicle, and the homotypical division after a spermatozoön has penetrated the zona pellucida. Thomson * has submitted evidence to show that in man both polar bodies are

FIG. 62.—A diagram showing the reduction in number of the chromosomes during the maturation of the ovum. The first division is heterotypical, the second homotypical.



extruded before the ovum is liberated from the follicle ; in other words, the process of maturation is completed before the ovum has been subjected to the influence of a spermatozoön. Additional evidence in favour of this view has been adduced recently as the result of the investigation of fresh material obtained at operations.†

THE SPERMATOZOÖN

The spermatozoa or male germ-cells are developed in the testes and are present in enormous numbers in the seminal fluid. Each consists of a small but greatly modified cell, and possesses a head, which represents the nucleus, a neck, a body or connecting piece, and a tail (fig. 63).

The **head** is ovoid or elliptical, but flattened, so that when viewed in profile it is pear-shaped. A layer of modified protoplasm, named the *head-cap*, covers its anterior two-thirds, and ends in front in a sharp edge.

The **neck** is less constricted in the human spermatozoön than in the sparmatozoa of some of the lower animals. The *anterior centriole* is situated at the junction of the head and neck, and behind it there is a band of homogeneous substance.

The **body** or **connecting piece** is rod-like, and is limited behind by a *terminal disc* or *ring*. The *posterior centriole* is placed at the junction of the body and neck, and from it an *axial filament*, surrounded by a sheath, runs through the body and tail. In the body the sheath of the axial filament is encircled by a *spiral thread*, which is enclosed in an envelope containing chondriosomes or mitochondria granules, and termed the *mitochondrial sheath*.

The **tail** consists of the axial thread or filament, surrounded by a thin protoplasmic sheath ; the terminal portion or *end-piece* of the tail is composed of the axial filament only.

Krause gives the length of the human spermatozoön as between 52μ and 62μ, the head measuring 4μ to 5μ, the connecting piece 6μ, and the tail from 41μ to 52μ.

By virtue of their tails, which act as propellers, the spermatozoa are capable of free movement, and ascend from the vagina into the cavity of the uterus, and from the latter into the uterine tube ; if placed in favourable surroundings

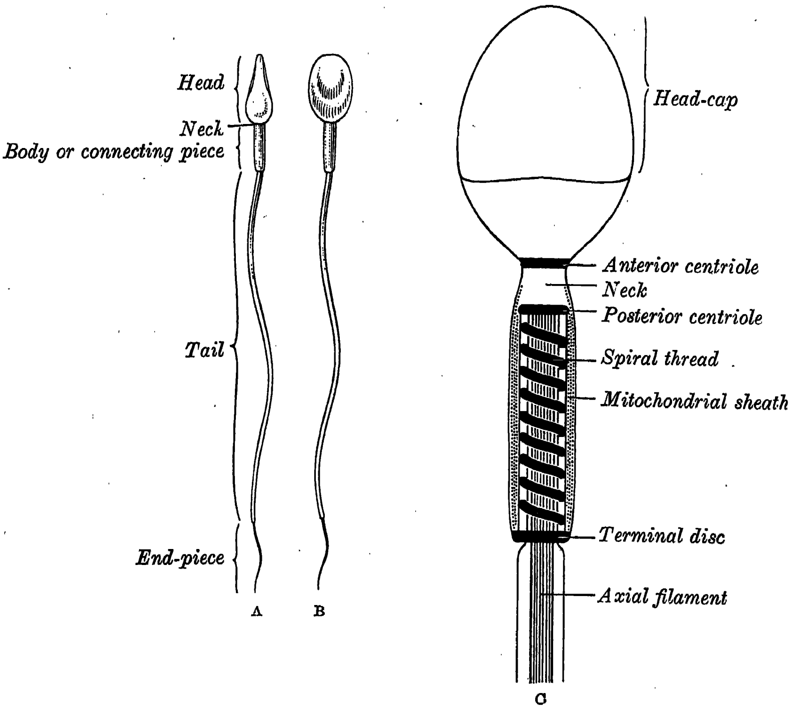
* *Loc. cit.* † Edgar Allen and others. *Loc. cit.*

(e.g. in the female passages) they will retain their vitality and fertilising power for several days.

The spermatozoa are developed from the primary germ-cells (p. 192) imbedded in the testes, and the stages of their development are very similar to those of the maturation of the ovum. The primary germ-cells undergo division and produce a number of cells termed *spermatogonia*.

After a number of mitoses the spermatogonia enter on a resting phase and gradually change, without further division, into *primary spermatocytes*. During this period the cell body enlarges, the mitochondria increase in number, and

Fig. 63.—A human spermatozoön, highly magnified. A. Profile view. B. Surface view. (After Retzius.) C. A diagrammatic representation of the head, neck and connecting piece, more highly magnified. (Modified from Meves.)

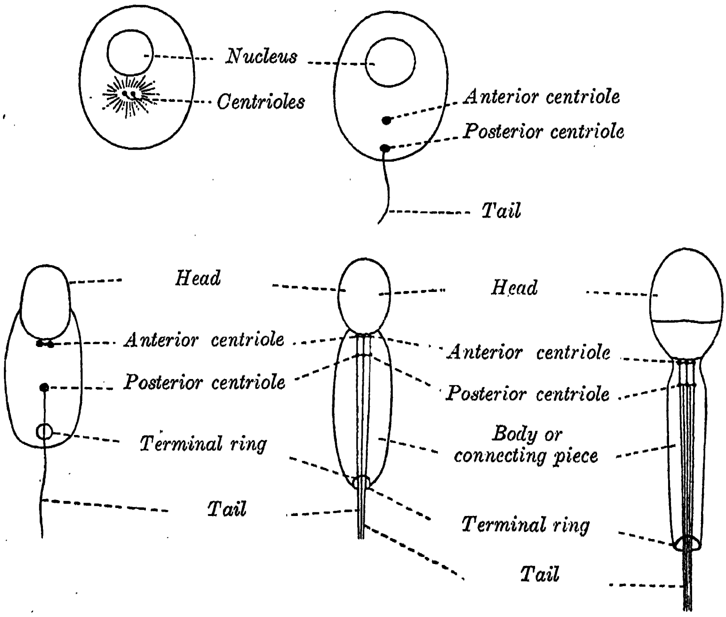


the centrosome, previously difficult to identify, becomes easy to recognise. The nuclear changes, which are of a very complicated character, result in a process of conjugation of the chromosomes, whereby their number is reduced to one-half. The chromosomes of the spermatogonia include two sex chromosomes, one of which, the x-chromosome, is identical with the sex chromosomes of the oögonia ; the other is very diminutive and is termed the y-chromosome. During conjugation the x- and the y-chromosomes become mated. It should be stated that many authorities deny the existence of a y-chromosome in man, and believe that during conjugation the x-chromosome does not mate.

The primary spermatocyte now proceeds to divide by a heterotypical mitosis into two apparently equal *secondary spermatocytes*, each of which possesses one-half of the number of chromosomes which is typical for the species. The only difference between them involves the sex chromosomes. When division occurs, the mated x- and y-chromosomes separate and pass to opposite poles of the spindle, so that one becomes included in one secondary spermatocyte, and the other in the other. After a brief resting phase each secondary spermatocyte divides, by a process of homotypical mitosis, into two *spermatids*. Division affects the x- and y-chromosomes as well as the others, and of the four spermatids which result from the division of each primary spermatocyte, two possess x-chromosomes and two possess y-chromosomes, while all four contain half of the number of chromosomes which is typical for the species.

Interesting changes occur during the conversion of the spermatid into the spermatozoön (fig. 64). At first the two centrioles lie side by side, but they soon alter their positions so that one comes to be placed deeper than the other; the deeper one forms the anterior centriole of the neck. The axial filament grows out from the superficial centriole, which divides into an anterior and a posterior part. The anterior part forms the posterior centriole of the neck, while the posterior part, which is ring-like, migrates to the distal end

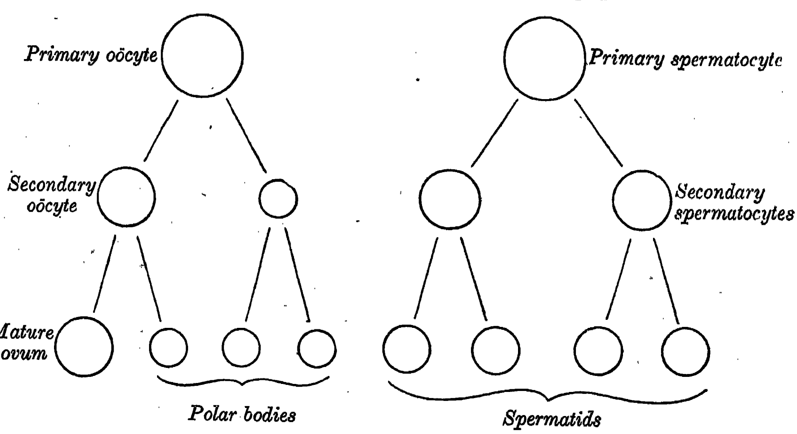
FIG. 64.—The transformation of a spermatid into a spermatozoön. Diagrammatic. (Modified from Meves.)



of the connecting piece or body and there forms the terminal disc or ring, through which the axial filament passes. The nucleus of the spermatid forms the head of the spermatozoön, and the cytoplasm, the investing sheath of the body and tail.

On comparing the development of the spermatozoön with the maturation of the ovum or primary oöcyte (fig. 65) it will be observed that the primary spermatocyte gives rise to two secondary spermatocytes, and the primary

FIG. 65.—A scheme showing the analogies in the process of maturation of the ovum and the development of the spermatids (young spermatozoa).



oöcyte to the secondary oöcyte and the first polar body; the two secondary spermatocytes give origin to four spermatozoa, and the secondary oöcyte and first polar body to four cells, the mature ovum and three polar bodies. In the development of the spermatozoön, and in the maturation of the ovum, there is

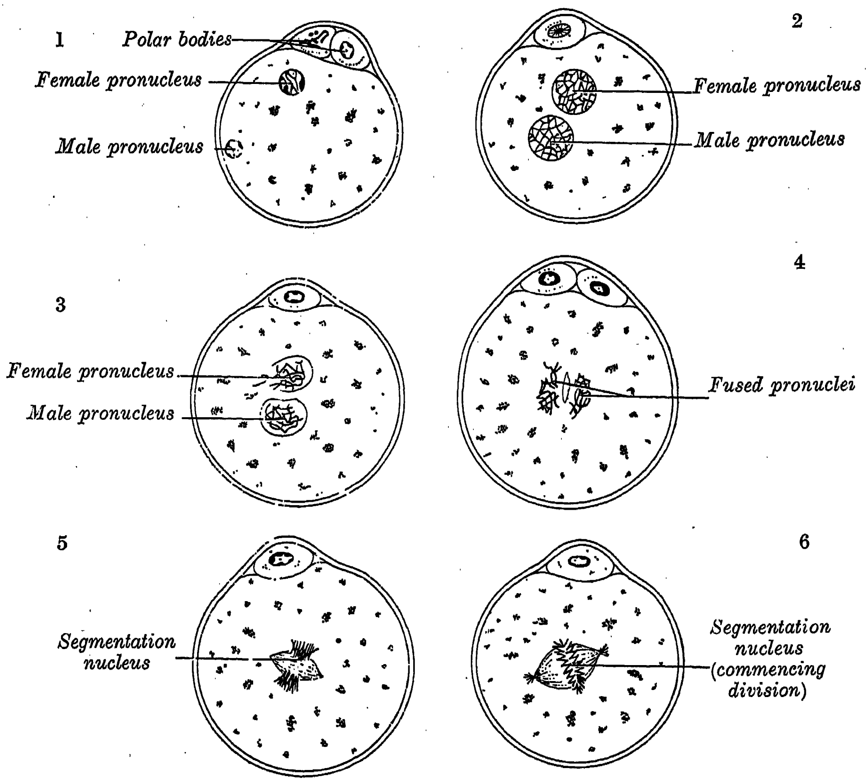
a reduction of the nuclear chromosomes to one-half of those present in the parent cell, and in each case the reduction is preceded by a process of conjugation of the chromosomes. But here the similarity ends, for it must be noted that the four spermatozoa are of equal size, and each is capable of fertilising a mature ovum, whereas the three polar bodies are much smaller than the mature ovum, are incapable of further development, and may be regarded as abortive ova.

THE FERTILISATION OF THE OVUM

Fertilisation consists of the union of a spermatozoön with a mature ovum (fig. 66). Nothing is known as to the fertilisation of the human ovum, but the various stages of the process have been studied in other mammals, and from the knowledge so obtained it is believed that fertilisation of the human ovum takes place in the lateral or ampullary part of the uterine tube.

A spermatozoön pierces the zona pellucida and enters the mature ovum, the point of entry being closed at once to prevent the admission of other spermatozoa. If the ovum has not thrown off its second polar body, it does so immediately after the entry of the spermatozoön. At the same time the

FIG. 66.—The process of fertilisation in the ovum of a mouse. (After Sobotta.)



latter sheds its tail, whilst its head and body become altered to form the *male pronucleus* and two centrosomes. The male pronucleus increases in size by absorbing fluid from the ovum, and there develops in its immediate neighbourhood a radial arrangement of the granules of cytoplasm, which has been termed the *aster of fertilisation*.

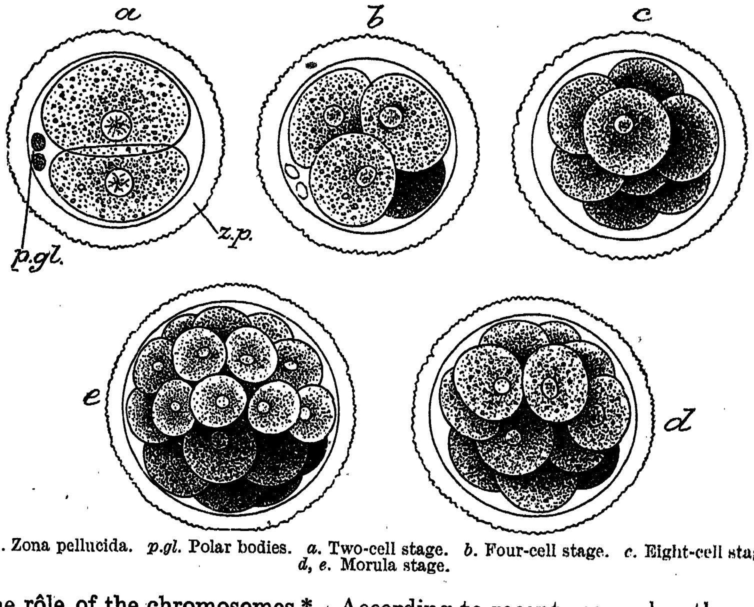
At the time of the entry of the spermatozoön, the ovum has laid up such a store of nutriment that there would appear to be danger of its dying from autointoxication. The contact of the spermatozoön has a striking effect. A wave of contraction passes over the ovum from its upper pole and a quantity

of deutoplasm is extruded from the cell and comes to lie between it and the zona pellucida. This process is termed *deutoplasmolysis*. It appears to have a beneficial effect on the ovum, freeing its cytoplasm of waste products and enabling it more easily to orientate itself within the zona pellucida. The process effects an alteration in the polarity of the ovum, for the two pronuclei approach each other in the centre of the cell or even at what was previously the lower pole.

The two pronuclei fuse with each other and give rise to the *segmentation nucleus*. This step is the essential feature of fertilisation. The nucleus so formed now possesses the number of chromosomes which is typical for the species, and one-half of them has been derived from the ovum and one-half from the spermatozoön. Following the fusion of the pronuclei the aster of fertilisation disappears, and the centrosomes of the spermatozoön separate from one another and proceed to opposite poles of the segmentation nucleus. The chromatin network breaks down and the chromosomes arrange themselves in an equatorial plane in the spindle formed between the two centrosomes. They then divide and retreat from the equator in opposite directions. Intense activity of the cytoplasm is apparent at this stage and results in the segmentation of the ovum into two daughter cells which are nearly equal in size. The next stage, viz. the segmentation of the ovum, has now begun.

Applied Anatomy.—Sometimes the fertilised ovum is arrested in the uterine tube, and undergoes development there, giving rise to a *tubal pregnancy*; or it may fall into the abdominal cavity and produce an *abdominal pregnancy*; occasionally it is not expelled from the vesicular follicle when the latter ruptures, but is fertilised within the follicle and produces what is known as an *ovarian pregnancy*. Under normal conditions only one spermatozoön enters the yolk and takes part in the process of fertilisation.

FIG. 67.—The first stages of the segmentation of a mammalian ovum. Semidiagrammatic. (From a drawing by Allen Thomson.) (Quain's Elements of Anatomy.)



z.p. Zona pellucida. p.gl. Polar bodies. a. Two-cell stage. b. Four-cell stage. c. Eight-cell stage. d, e. Morula stage.

The rôle of the chromosomes.*—According to recent researches the mature ovum contains within itself all the materials essential for the formation of a new being, and in the lower forms at least may produce such, when its potential energy is converted into free energy by suitable mechanical or physico-chemical means. Loeb and others have been able to imitate the process of fertilisation in sea-urchins, frogs, etc., by altering the osmotic pressure of the unfertilised ovum.

* Consult *The Organism as a Whole*, by Jacques Loeb; *The Physical Basis of Heredity*, by Morgan; and *The Mechanism and Physiology of Sex Determination*, by Goldschmidt, translated by Dakin.

Reference has already been made to the fact that the spermatozoa, in equal numbers, contain either an x- or a y-chromosome, and that the mature ovum contains one x-chromosome. If an ovum be fertilised by a spermatozoön containing an x-chromosome, the cells of the embryo will each contain two x-chromosomes and the embryo will be female, but if an ovum is fertilised by a spermatozoön containing a y-chromosome, the cells of the embryo will each contain one x- and one y-chromosome and its sex will be male.

This, however, is not the only factor involved in the determination of sex. The theory advanced is that the chromosomes contain materials which initiate and control, by chemical means, the processes that lead to the development of the various tissues and their individual peculiarities. The establishment of a sex-difference is therefore, in the first instance, dependent on a specialised chromosome, but the development of the sexual features results from the presence of specialised chemical substances in the chromosomes.

The ova of certain animals contain a variable amount of pigment which, as the result of fertilisation, undergoes rearrangement in a very regular manner so as to form a crescentic area, intermediate in tint between the darkly pigmented area and the lighter polar area. This has been termed the "grey crescent." Its central, deeper portion controls the growth of the head and exerts an influence over the horns of the crescent, which are responsible for the formation of the right and left halves of the trunk and the corresponding limbs.* The polarity of the fertilised ovum is therefore fixed at a very early stage, and it would appear that, in many animals at least, the plane of bilateral symmetry is determined by the line of entry of the spermatozoön. Nevertheless it must be remembered that the cells derived from the ovum by its early segmentations are totipotent. Consequently a fertilised ovum may later divide into two equal parts, each of which may go on to form a complete embryo (*uniovular twins*), although under normal conditions it will only give rise to a single embryo.

THE SEGMENTATION OF THE FERTILISED OVUM

The early stages in the development of the human ovum have not yet been seen, but from what is known to occur in other mammals it may be regarded as certain that the process of segmentation starts immediately after fertilisation, i.e. while the ovum is in the uterine tube. The nucleus exhibits the usual changes, and these are succeeded by division of the fertilised ovum into two cells of nearly equal size. The process is repeated again and again, so that the two cells are succeeded by four, eight, sixteen, thirty-two, and so on, with the result that a mass of cells is formed, and to this mass the term *morula* is applied (fig. 67). During these changes the intense activity of the cytoplasm of the cells is evidenced by the constant streaming of their contained granules. The individual cells do not remain motionless but restlessly alter their positions relative to one another and reorientate themselves within the zona pellucida in order to maintain the bilateral symmetry of the ovum.

Before segmentation occurs the amount of cytoplasm in the fertilised ovum is great out of all proportion to the size of the nucleus, and the initial divisions which result in the formation of the morula have the effect of reducing the disproportion until the cytoplasm bears to the nucleus the average relationship which obtains in the average somatic cells of the species. As soon as this stage is reached the zona pellucida must disappear, for the continued process of segmentation thereafter results in an increase in the size of the ovum as a whole.

The process of differentiation, which plays such an important part in the formation of the embryo, commences in the cells of the morula. Its outermost layer constitutes the *trophoblast*, and the cells in its interior differentiate into a closely packed *inner cell mass* or *formative mass*, and a loosely arranged *primary mesoderm* † (fig. 71).

The cells of the trophoblast subsequently differentiate into an inner cellular layer, which is termed the *cytotrophoblast*, and an outer syncytial layer termed the *plasmodial trophoblast*, in which growth is so active that the nuclear divisions

* Brachet, A., *Quarterly Review of Biology*, 1927.

† It would be more accurate to term this tissue mesenchyme (see p. 62).

are not accompanied by divisions of the cytoplasm, and there is no cellular definition. The plasmodial trophoblast exerts a histolytic action on the uterine mucosa, and not only effects the imbedding of the ovum in the maternal tissues but also, at a slightly later stage, opens up the channels by means of which the developing embryo is enabled to draw nourishment from the maternal blood.

While these changes are occurring in the trophoblast, the inner cell mass

FIG. 68.—A section through the blastodermic vesicle of Vespertilio murinus. (After van Beneden.)

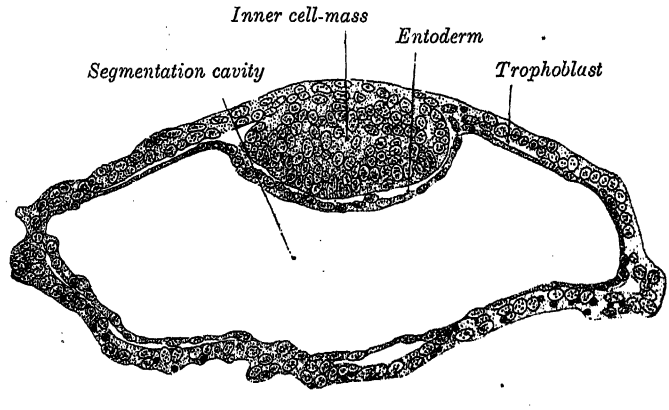


FIG. 69.—A section through the embryonic disc of Vespertilio murinus. (After van Beneden.)

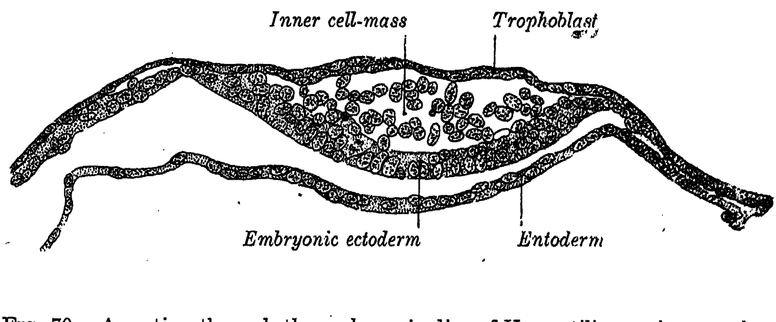
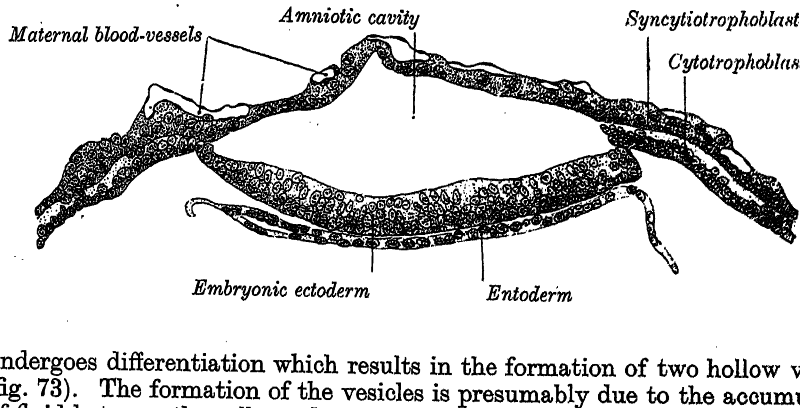


FIG. 70.—A section through the embryonic disc of Vespertilio murinus to show the formation of the amniotic cavity. (After van Beneden.)



undergoes differentiation which results in the formation of two hollow vesicles (fig. 73). The formation of the vesicles is presumably due to the accumulation of fluid between the cells, and as it increases in amount the cells arrange themselves in a surrounding wall. Of the two vesicles so formed, one remains in close contact with the trophoblast and constitutes the *ectodermal* or *amnio-*

embryonic vesicle. The other is placed more centrally and is at first the smaller of the two. It constitutes the *entodermal vesicle,* and is often referred to as the *archenteron* or *yolk sac.**

While differentiation is occurring in the trophoblast and in the inner cell mass, changes are taking place in the primary mesenchyme. The fluid in which its constituent cells are floating tends to collect centrally and the cells become relegated to the periphery, where they eventually form a layer on the inner surface of the cytotrophoblast and on the outer surfaces of the entodermal and ectodermal vesicles. In this way a cavity, filled with a fluid rich in albuminous material, comes to surround the vesicles almost completely. It is termed the *magma cavity,* and it subsequently forms the extra-embryonic cœlom (figs. 73, 90). Its wall, which consists of trophoblast lined with primary mesenchyme, constitutes the *chorion.*

Concomitant with the changes which have just been described, and which transform the morula into a *blastocyst,* the ovum is gradually carried along the uterine tube by the action of the cilia of its lining epithelium. It is uncertain

FIG. 71.—A diagram showing the differentiation of the inner cell-mass.

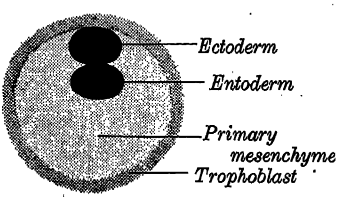


FIG. 72.—A diagram showing the ectodermal and entodermal vesicles and an early stage in the formation of the extraembryonic cœlom.

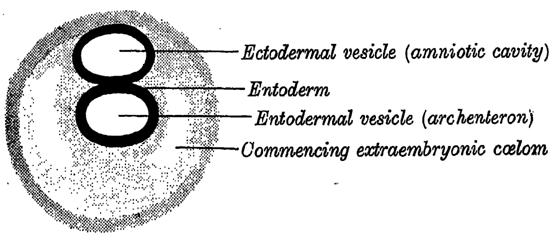
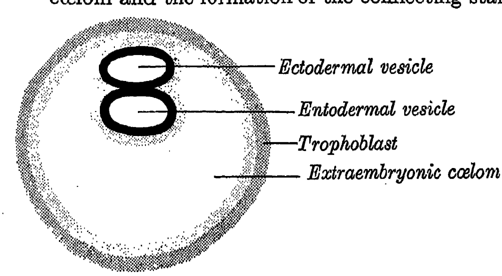


FIG. 73.—A diagram showing the completion of the extra-embryonic cœlom and the formation of the connecting stalk.



how long an interval elapses between the fertilisation of the ovum and its arrival in the uterus. † The passage along the tube probably covers a period of not less than three and not more than seven or eight days and this interval allows the uterine mucous membrane to prepare itself for the reception of the fertilised ovum (p. 78). It is probable that the ovum retains its zona pellucida until it leaves the uterine tube, and it is believed that it remains within the uterus for a short time before it becomes imbedded. During this interval the trophoblast undergoes differentiation, and the imbedding is effected owing to the histolytic action of the plasmodial trophoblast on the uterine mucosa, by means of which the ovum literally burrows its way into the wall of the uterus.

One of the earliest human ova yet obtained for examination was described by Professors Bryce and Teacher in 1908. It had already reached the stage

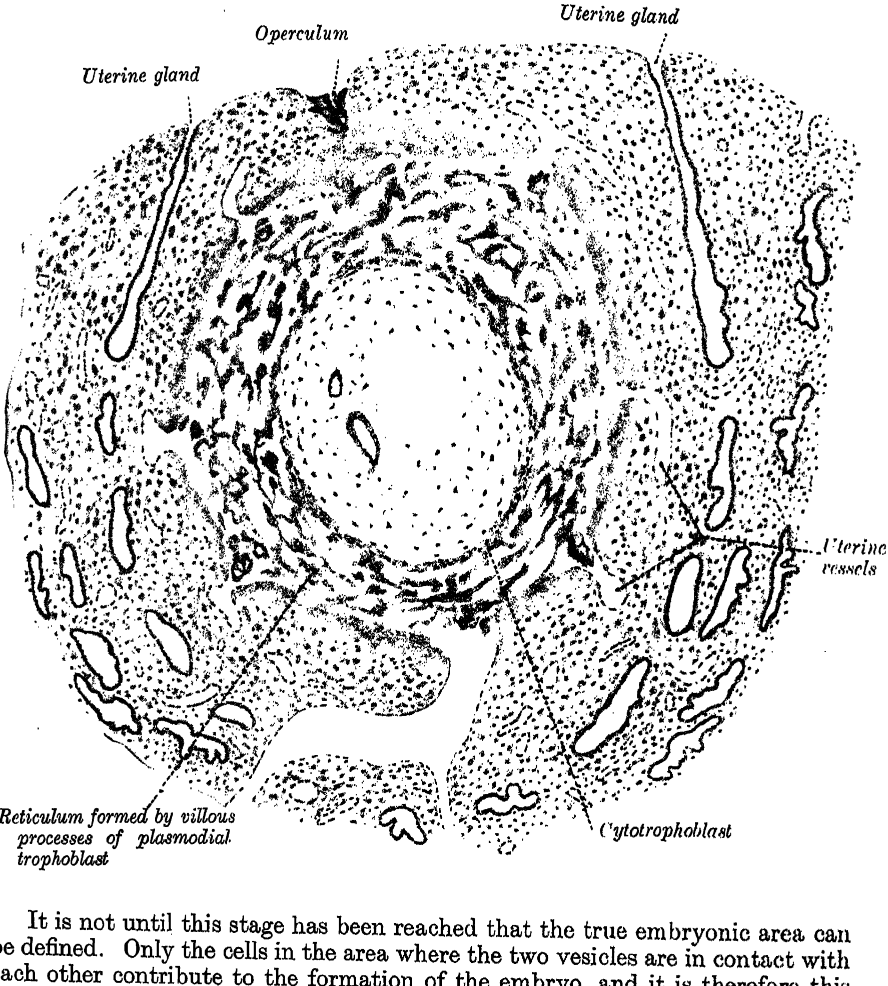
* H. Stieve (*Zeitschrift für Mikroskopisch-Anatomische Forschung,* Bd. 40, 1936) holds that the yolk-sac does not arise in this way. In the Werner ovum, which he claims represents an earlier stage of development than the Teacher-Bryce ovum described on this page, the entoderm is represented only by a simple plate of cells closely applied to the ventral aspect of the amnio-embryonic vesicle, which is already present. In Stieve's view the yolk-sac is formed by an extension of the peripheral cells of this plate into the magma cavity, a portion of which is surrounded and shut off in the process.

In this connexion consult a paper by P. N. B. Odgers in the *Journal of Anatomy,* vol. lxxi. 1937.

† G. W. Corner, *Contributions to Embryology,* vol. xiii. 1921.

which has just been outlined, and its age has been estimated at 13-14 days. The ovum (fig. 74) was imbedded in the uterine wall, where villous processes of the plasmodial trophoblast formed an actively growing reticulum. The interior of the blastocyst contained an ectodermal vesicle, connected to the trophoblast by a short stalk not seen in the figure, and an entodermal vesicle, imbedded in a loose bed of primary mesenchyme. The magma cavity was present in an early stage of formation. Owing to shrinkage during fixation the ectodermal and the entodermal vesicles were no longer in contact with each other but were some little distance apart.

FIG. 74.—Section of early human embryo (Teacher-Bryce I.) with decidua and implantation cavity. From Bryce's "Observations on the Early Development of the Human Embryo," *Transactions of the Royal Society of Edinburgh*, 1924.

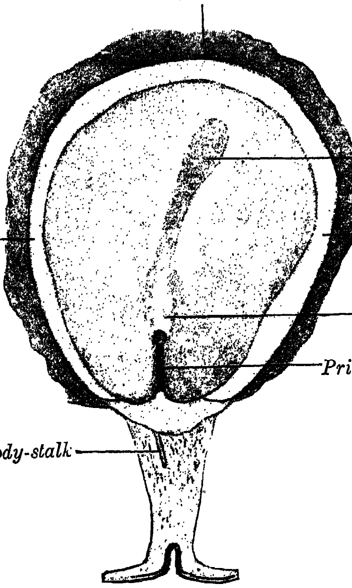


It is not until this stage has been reached that the true embryonic area can be defined. Only the cells in the area where the two vesicles are in contact with each other contribute to the formation of the embryo, and it is therefore this contact region which is termed the *embryonic area* or *shield*. It is noteworthy that of the thousands of cells derived from the ovum at this stage only a relatively small number take part in the formation of the embryo, while the vast majority form its covering and nourishing membranes and certain other extra-embryonic structures to be noted later. The ectodermal cells of the embryonic area are columnar in type and are marked off from the entoderm by a limiting membrane. By the third week they form three or four interlocking rows of cells (fig. 77). The ectodermal cells of the amnion are flatter and more elongated and form only a single stratum. The entodermal cells of the embryonic area are flattened, but those lining the rest of the entodermal vesicle or yolk-sac

vary in appearance and patches of cubical or low columnar cells are found, especially on the caudal wall. Except in certain situations to be noted later, the entoderm never forms more than a single layer of cells.

There are, however, two other features of the embryo at this time which deserve mention. The presence of a short stalk connecting the amniotic or ectodermal vesicle to the trophoblast has already been noticed. This stalk, which consists of primary mesenchyme, contains in its interior a duct which communicates with the amniotic cavity but ends blindly near the trophoblast. A somewhat similar stalk has been found in some specimens

FIG. 75.—An embryo of Hylobates concolor. Dorsal aspect, with the amnion laid open. (After Selenka.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



extending from the entodermal vesicle into a strand of primary mesenchyme which connects the vesicle to the trophoblast. These two ducts are both transient features, but they have a very different significance.

In the reptilia, and in many mammals, the amnion arises as a fold around the embryonic area which soon closes in to form a vesicle. The amniotic duct may be regarded as an indication of the abridgment of this process in the human embryo, in which, as has already been seen, the amnion arises as a cavity within the inner cell mass. The duct of the entodermal vesicle or yolk-sac has quite a different significance. In many mammals the entodermal vesicle is much larger and occupies nearly the whole interior of the blastocyst, and the presence of the duct in the human embryo may be regarded as evidence that the primates evolved from a stock in which the entodermal vesicle was a much larger organ.

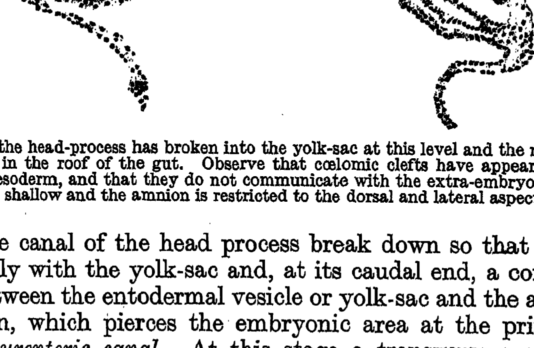
The differentiation of the embryonic area.—The embryonic area shows no distinguishing features in its earliest stages. At first nearly circular, its outline rapidly alters and becomes oval, indicating the long axis of the body. The oval area becomes pear-shaped, and in the median plane of its narrower portion there appears a localised opacity, which soon elongates to form a linear opacity, termed the *primitive streak* (fig. 75). It must be remembered that in the early stages of development the living tissues are translucent, but any localised thickening due to cellular proliferation naturally interferes with the translucency and causes a localised opacity. The presence of the primitive streak indicates that rapid growth is occurring throughout its site. At the headward end of the primitive streak an area of exceptionally active growth develops and forms a knob-like thickening which is termed the *primitive node*. At the caudal end of the embryonic area the ectoderm and entoderm are very intimately related over a limited region which subsequently forms the *cloacal membrane*.

From the primitive node a rod-like process of cells grows headwards in the median plane and separates the ectoderm of the embryonic area from the subjacent roof of the entodermal vesicle (fig. 96). This is termed the *head process*, and it is the forerunner of the skeletal axis of the body. The solid rod of cells becomes canaliculised (fig. 76) and at its caudal end the canal breaks through on to the ectodermal surface at the primitive node. The entodermal cells lying ventral to the head process disappear, and the head process is then a constituent part of the roof of the yolk-sac in the median plane. The cells forming

Fig. 76.—Transverse section of the tail-fold of a human embryo, about 19 days old (Embryo: Bryce-McIntyre). From Bryce's "Observations on the Early Development of the Human Embryo," *Transactions of the Royal Society of Edinburgh*, 1924.

The canaliculised head-process lies in the roof of the hind-gut. The primitive streak and groove lie on the ventral aspect of the tail-fold. Observe that the secondary mesoderm is continuous ventrally with the primitive streak, and that the tail-fold is lying within the amniotic cavity.

Fig. 77.—Transverse section of a human embryo, about 19 days old (Embryo: Bryce-McIntyre). From Bryce's "Observations on the Early Development of the Human Embryo," *Transactions of the Royal Society of Edinburgh*, 1924.



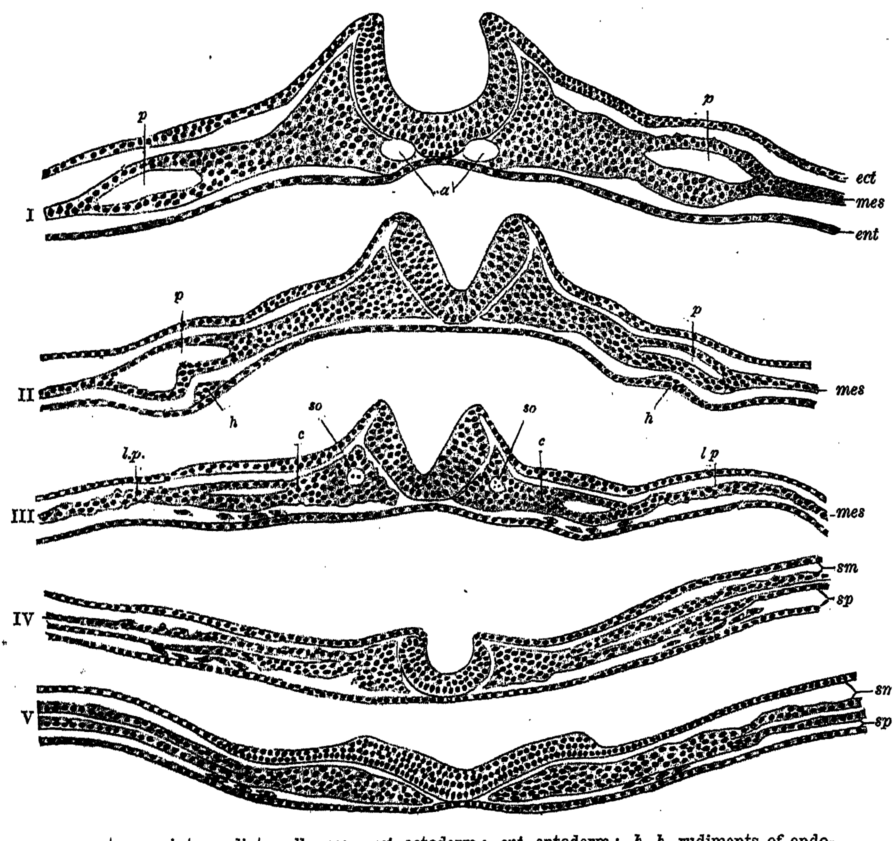
The canal of the head-process has broken into the yolk-sac at this level and the notochordal plate is incorporated in the roof of the gut. Observe that cœlomic clefts have appeared in the lateral plates of the mesoderm, and that they do not communicate with the extra-embryonic cœlom. The neural groove is shallow and the amnion is restricted to the dorsal and lateral aspects of the embryo.

the floor of the canal of the head process break down so that the canal communicates freely with the yolk-sac and, at its caudal end, a communication is established between the entodermal vesicle or yolk-sac and the amniotic cavity. This connexion, which pierces the embryonic area at the primitive node, is termed the *neurenteric canal*. At this stage a transverse section across the embryonic area shows that, in the median plane, the roof of the entodermal vesicle is formed by the cells of the head process (fig. 77), and this intercalation extends forwards to the region which will subsequently form the pharynx. Later, these cells of the head process become excalated out from the entoderm

and form the *notochord*, the roof of the entodermal vesicle being repaired by the fusion of the adjoining entodermal cells. Subsequently the cells of the notochord develop around them a homogeneous sheath, and the continued proliferation of the cells within the sheath results in the formation of a solid but flexible rod, which becomes surrounded by the mesenchyme of the primitive or membranous vertebral column (p. 83).

FIG. 78.—A series of transverse section through the embryo of a dog. (After Bonnet.) (From Quain's Elements of Anatomy, vol. i., Embryology.)

Section I is the most anterior. In V the neural plate is spread out nearly flat. The series shows the uprising of the neural folds to form the neural canal.



a, aortæ; *c*, intermediate cell-mass; *ect*, ectoderm; *ent*, entoderm; *h*, *h*, rudiments of endothelial heart-tubes. In III, IV, and V the scattered cells represented between the entoderm and splanchnic layer of mesoderm are the vasoformative cells which give origin in front, according to Bonnet, to the heart tubes *h*; *l.p.*, lateral plate still undivided in I, II, and III; in IV and V split into somatic (*sm*) and splanchnic (*sp*) layers of mesoderm; *mes*, mesoderm; *p*, pericardium; *so*, primitive segment.

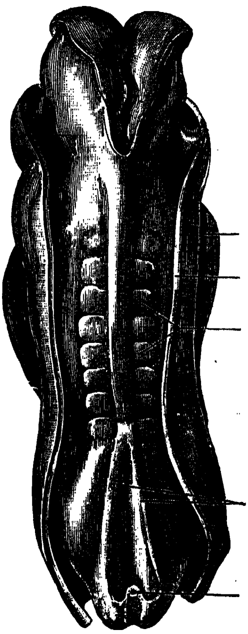
During the earlier part of this period another important change occurs which affects nearly the whole of the embryonic area. From the sides of the primitive streak there is an intensely active cell growth. These cells spread laterally and forwards until they extend over the whole embryonic area *with the exception of the median plane*. They insinuate themselves between the ectoderm and the underlying entoderm and constitute a third constituent layer, which is termed the *secondary mesoderm* (fig. 76). At the extreme cephalic end of the area the secondary mesoderm does cross the median plane, constituting what has been termed the '*pericardial bar.*'

The primitive streak is not the only source of secondary mesoderm. Cephalic to the headward end of the head process, the entoderm in the roof of the yolk-sac becomes thickened and gives rise to a plate of large, vesiculous cells which has been termed the *prochordal plate*. This plate contributes secondary mesoderm to the head region, and the cranial end of the head process gives origin

to two lateral mesodermal bands, which may be regarded as representing the gastral mesoderm * (p. 65).

In the wider cephalic end of the oval embryonic area the ectoderm thickens to form a curved ridge, the lateral limits of which extend caudally until they pass beyond the primitive node. This second thickening constitutes the *medullary plate*, from which by far the greater part of the central nervous system is

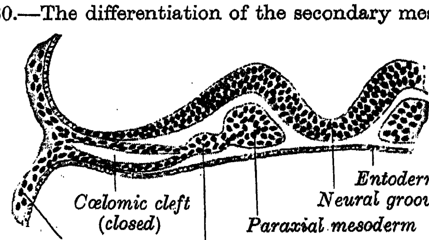
FIG. 79.—A human embryo, 2·1 mm. long. Dorsal aspect. (From a model by Eternod.)



developed. The raised ridges constitute the *neural folds*, and the median groove which separates them is the *neural groove.*

As the embryonic area increases in length the neural folds deepen at the anterior end of the area and the walls of the groove become expanded (fig. 78). This enlargement is the first sign of brain formation. It is not a continuous enlargement, however, for two transverse constrictions indicate a subdivision

FIG. 80.—The differentiation of the secondary mesoderm.



into three parts, viz. the *prosencephalon* or *fore-brain*, the *mesencephalon* or *mid-brain*, and the *rhombencephalon* or *hind-brain*. Between the fore-brain and the pericardial bar of mesoderm the ectoderm and entoderm come into contact over a small area, forming the *buccopharyngeal membrane* (fig. 174). As the neural groove deepens, its dorsal edges come into contact with each other and fuse to convert the groove into a somewhat slit-like canal. Fusion occurs first in the region of the hind-brain (fig. 79) and extends both headwards and tailwards, until only a small opening is left at each end. These openings are termed

* J. P. Hill and J. Florian, *Journal of Anatomy*, vol. lxv. 1931.

the anterior and posterior *neuropores* ; both close towards the end of the fourth week. The cells which connect the fused dorsal edges of the neural groove to the overlying ectoderm constitute the *neural crest epithelium* (fig. 139), the history of which will be considered in a subsequent section (p. 108).

The fusion of the dorsal lips of the neural groove in the region of the brain results in the formation of the three *primary cerebral vesicles.* The walls of these vesicles become thickened and develop into the nervous tissue and neuroglia of the brain, and the cavities are modified to form the ventricles of the brain. The remainder of the tube forms the spinal cord, its cavity persisting as the central canal.

Throughout the region of the notochord the secondary mesoderm arranges itself in (1) a thickened medial portion which lies immediately lateral to the neural groove and is termed the *paraxial mesoderm* (fig. 80), (2) a narrower portion, termed the *intermediate cell mass,* situated to its lateral side and directly continuous with it, and (3) a flattened lateral portion, continuous medially with (2), which extends over the surface of the embryonic area to its periphery, where it becomes continuous with the primary mesenchyme on the outer surfaces of the ectodermal and entodermal vesicles. This portion is termed the *lateral plate.*

The appearance of the secondary or intra-embryonic mesoderm completes the first stage of differentiation in the embryonic area. The embryo now consists of an outer, protective layer, the ectoderm, an inner nutritive layer, the entoderm, and an intermediate layer, the mesoderm, which is available primarily as a muscle-forming layer. It is clear from their history and their early differentiation that these layers are of considerable significance, but too much stress must not be laid on their independence from one another. In other words, the differentiation reached at this stage has not gone so far as to leave the constituent cells of the three layers with potencies so limited that complete divergence is assured for the future. The potencies of the individual cell layers are reduced from the totipotent condition found at an earlier period, but not to such an extent that the potencies of the cells of one layer are entirely different from those of the two remaining layers.

Broadly stated, however, the three layers in the human embryo contribute to the formation of systems and organs which show distinct functional differences.

The **ectoderm** consists of columnar cells, which, however, become somewhat flattened or cubical, especially towards the periphery of the embryonic area. It gives origin to : (1) the skin and the lining cells of the glands which open on it, and its appendages, the hair and nails ; (2) practically the whole of the nervous system, including the cranial and spinal ganglia, the sympathetic ganglia and the posterior lobe of the hypophysis cerebri ; (3) the chromaffin organs ; (4) the anterior lobe of the hypophysis cerebri ; (5) the epithelium of the cornea, conjunctiva and lacrimal glands ; (6) the lens ; (7) the plain muscle of the iris ; (8) the neuro-epithelium of the sense-organs ; (9) the epithelium lining the nose and the paranasal sinuses, the roof of the mouth, the gums, and the cheeks ; (10) the salivary glands and the enamel of the teeth ; and (11) the lower part of the anal canal.

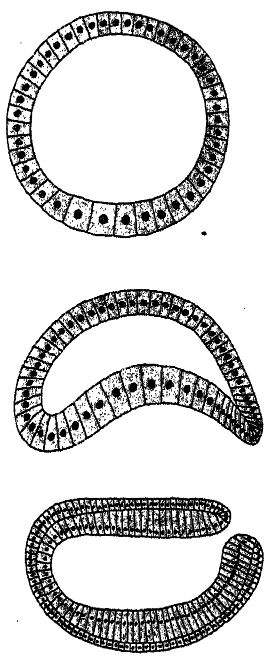
The **entoderm** consists at first of flattened cells, which subsequently become columnar. It gives origin to : (1) the epithelial lining of the whole of the alimentary canal, with the exception of those portions already ascribed to the ectoderm ; (2) the lining cells of all the glands which open into the alimentary canal, including the liver and the pancreas, but excluding the salivary glands ; (3) the epithelium lining the pharyngo-tympanic tube and the tympanic cavity ; (4) the epithelium of the thyroid and parathyroid glands and the thymus ; (5) the lining epithelium of the larynx, trachea and the smaller air passages, including the alveoli and the air-sacs ; (6) the epithelium of most of the urinary bladder and the adjoining part of the urethra ; (7) the epithelium of the prostate.

The **mesoderm** gives origin to the remaining organs and tissues of the body. These include : (*a*) all the connective tissues, including bone and cartilage, i.e. the whole skeletal system, and the blood ; (2) the teeth, with the exception of the enamel ; (3) the whole musculature of the body, both striated and unstriated,

with the exception of the musculature of the iris ; (4) the blood-vascular and lymphatic systems ; (5) the urogenital system, with the exception of most of the urinary bladder, prostate and urethra ; (6) the cortex of the suprarenal glands and the endothelial linings of the pericardial, pleural and peritoneal cavities.

It should be observed that the cells of the mesoderm are very soon differentiated into those which subsequently retain their close-packed cellular character (*mesoderm proper*) and those which form a loose tissue with a fluid matrix (*mesenchyme*). Thus the muscles and urogenital organs are mesodermal while the connective tissues are mesenchymatous, and on account of the fluid character of the matrix their cellular elements are able to alter their position by active migration (p. 83). The term *mesothelium* is sometimes applied to epithelial cells of mesodermal origin, such as the secretory epithelium of the kidney, the cortical cells of the suprarenal glands, and the endothelium lining the serous cavities.

FIG. 81.—Three stages in the development of amphioxus (after Hatschek.)



A

B

C

A. Spherical blastoderm. The cells at the lower pole are larger than those at the upper pole.
B. Invagination of the lower pole to form a gastrula.
C. Longitudinal section through the embryo at a slightly later stage. Gastrulation is completed and the primitive alimentary canal communicates with the exterior through the blastopore, which lies at the caudal end of the flattened dorsal surface of the embryo.

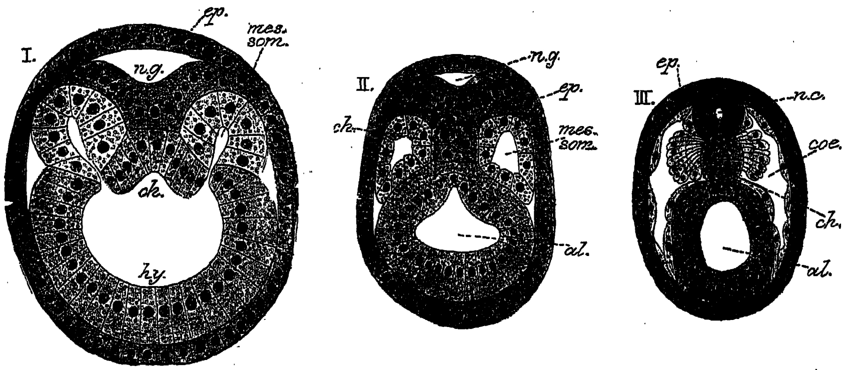
It may prove helpful at this point to compare the early history of the human ovum with that of other vertebrata and lower chordata. The ovum of amphioxus contains only a small amount of deutoplasm and, when fertilised, it segments first into two cells of equal size, the line of cleavage corresponding to the plane of bilateral symmetry. The second and third divisions, both in planes at right angles to the first, result in the formation of eight cells, of which the four at the upper pole are slightly smaller than the four at the lower pole. The egg continues to divide and eventually forms a hollow sphere or *blastula*, the larger cells still being situated at its lower pole. Even in the ovum it is possible to identify the material that is destined to give rise to the cells of the mesoderm, and its history has been investigated recently.* In the fully formed blastula entodermal, ectodermal and mesodermal areas can be identified. The entodermal cells are the largest, and the mesodermal are the smallest and are somewhat spherical in shape. At this stage the ectodermal cells along the anterior border of the entoderm are already undergoing differentiation and a '*chordal plate*' can be recognised. The hollow blastula becomes invaginated, and the chordal plate and the mesoderm are involved in this process in addition to the entoderm. As a result of this invagination the segmentation cavity of the blastula becomes crescentic (fig. 81, B), and is finally obliterated (fig. 81, C). The ovum has now been converted into a hollow cup-like mass or *gastrula*, the walls of which are two cells thick and enclose a cavity, termed the *archenteron*. This cavity communicates with the exterior through an orifice, which is termed the *blastopore*. The inner layer of the gastrula consists principally of entoderm, but its dorsal wall is formed in the median plane by the chordal plate and on each side by the mesoderm. In the succeeding growth changes the embryo becomes elongated and flattened along its dorsal aspect. At the same time the lips of the blastopore are approximated and the opening, much reduced in size, comes to lie at the caudal end of the flattened dorsal surface. While gastrulation is in progress, the cells in the region of the dorsal lip of the blastopore undergo rapid proliferation, which results in the formation and elongation of the dorsal surface of the embryo. Subsequent to the closure of the blastopore continued activity in this region is responsible for the further growth of the embryo in its long axis.

A median groove forms on the ventral aspect of the chordal plate in the roof of the

* E. G. Conklin, "The Embryology of Amphioxus," *Journal of Morphology*, vol. 54, Dec. 1932.

archenteron (fig. 82, I), and it becomes closed off from the cavity to form a rod of cells, which occupies the median plane between the neural tube and the archenteron (fig. 82, II). This rod forms the notochord and it remains for some time in continuity with the entoderm at its cephalic end. At the same time two parallel grooves form in the mesoderm on each side of the chordal plate (fig. 82, I), and become shut off from the archenteric cavity in such a way as to form two columns, which become constricted at intervals to give rise to the mesodermic somites (fig. 82, II). While these changes are in progress the entoderm extends

FIG. 82.—Transverse sections across an amphioxus embryo, showing the origin of the notochord and the intra-embryonic mesoderm (Hatschek). (Quain's Elements of Anatomy, xi. edition, Embryology.)

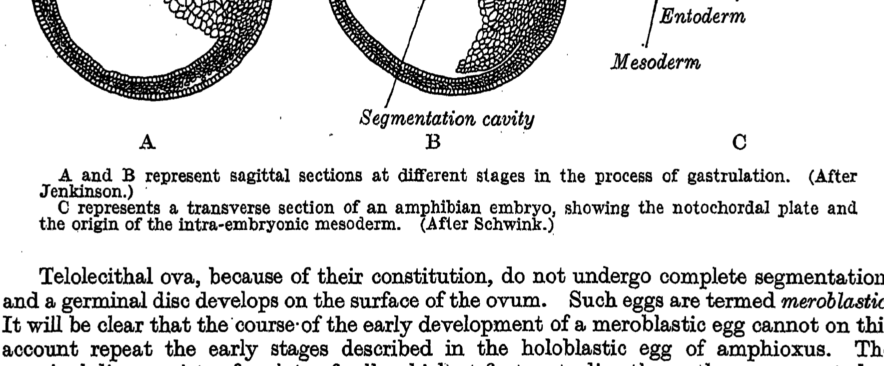


n.g. neural groove; *ch.* notochord; *ep.* ectoderm; *hy.* entoderm; *mes. som.* mesodermic somite; *n.c.* neural tube; *coe.* cœlom; *al.* archenteron.

dorsally on each side and forms a new roof for the archenteron, from which the chordal plate and the mesoderm have now been excluded. The mesoderm extends ventrally between the ectoderm and the entoderm, and its contained clefts constitute the cœlom (fig. 82, III).

It has been seen that the fertilised ovum of amphioxus undergoes complete segmentation, and such eggs are termed *holoblastic*. This condition is by no means general and is dependent on the quantity of deutoplasm in the ovum. The egg of amphioxus contains a relatively small amount of deutoplasm, and is termed *microlecithal*, but the eggs of fishes, reptiles, and birds contain a much larger quantity, being termed *lecithal* or *telolecithal*.

FIG. 83.—Early development of the fertilised egg of an amphibian.



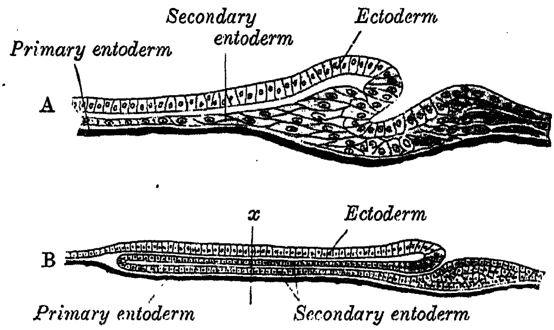
A and B represent sagittal sections at different stages in the process of gastrulation. (After Jenkinson.)

C represents a transverse section of an amphibian embryo, showing the notochordal plate and the origin of the intra-embryonic mesoderm. (After Schwink.)

Telolecithal ova, because of their constitution, do not undergo complete segmentation, and a germinal disc develops on the surface of the ovum. Such eggs are termed *meroblastic*. It will be clear that the course of the early development of a meroblastic egg cannot on this account repeat the early stages described in the holoblastic egg of amphioxus. The germinal disc consists of a plate of cells which at first rests directly on the unsegmented or incompletely segmented yolk. Soon a segmentation cavity appears which separates the smaller embryonic cells from the larger cells of the yolk mass on which it rests (fig. 83).

While this is occurring in the amphian egg a curved groove appears at the caudal margin of the disc, and its raised lip constitutes a region of intensely active growth. The groove deepens and the cells which form its roof constitute the entoderm. The formation of this groove and the active growth of entoderm from its margin constitutes a modified process of gastrulation and the raised lip constitutes the dorsal lip of what is actually a blastopore. It is, however, impossible for the large and incompletely divided cells of the yolk mass to be invaginated, and to compensate for this the ectodermal cells of the germinal disc grow over the surface of the yolk until they completely envelop it. This extension of the ectoderm over the yolk corresponds partly to the process of gastrulation and partly to the closing in

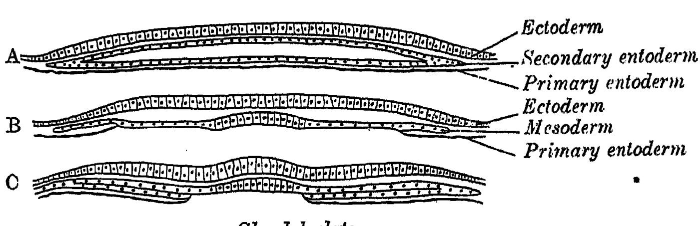
FIG. 84.—Sagittal sections through a reptilian egg (after Will).



A shows the formation of a depression at the caudal end of the embryonic disc.
B shows the invagination of the secondary entoderm.

of the blastopore, which is left as a small opening at the caudal end of the embryo, and is subsequently closed. The forward growth of the entoderm outlines the digestive cavity and its roof is formed by a ' chordal plate ' which subsequently becomes constricted off and forms the notochord. Before this occurs, however, this plate, while still a constituent part of the enteric roof, gives off from each side a mass of cells which grow ventrally in the interval between the ectoderm and the entoderm. They form the intra-embryonic mesoderm and split into two layers to enclose a cœlomic cavity. As the blastopore narrows a ring of mesoderm is found surrounding it, and the headward portion of this ring is continuous with the caudal end of the mesoderm of the chordal plate and may be regarded as being derived from it. The closure of the blastopore converts this ring into a solid mass, which adopts a median position and a linear outline. Its cells are indistinguishable from

FIG. 85.—Diagrammatic transverse sections of a reptilian embryo, showing the notochordal plate and the formation of the intra-embryonic mesoderm.



A represents a transverse section made at *X* in fig. 84, B. The tubular invagination of the secondary entoderm is seen between the ectoderm and the primary entoderm.
In *B* the adjoining portions of the primary and secondary entoderm have broken down, and the notochordal plate is seen in the roof of the primitive gut.
In *C* the primary entoderm is closing in on the notochordal plate and the intra-embryonic mesoderm is extending laterally on each side.

the covering ectoderm and the underlying entoderm, and they constitute the *primitive streak.*

Further modifications are found in the early development of the reptilian egg. As the ectoderm of the germinal disc grows over the surface of the yolk, a pit-like depression appears at the caudal end of the disc. This depression, however, does not behave in the same manner as in the amphibian egg, for the cells in its raised border differentiate into a superficial layer, the ectoderm, and an underlying mass of scattered cells, the deepest layer of which differentiates to form the primary entoderm of the roof of the digestive cavity. In the floor of the depression, which constitutes the primitive streak, it is not possible to dis-

tinguish the individual layers from one another. At the next stage the depression deepens and a groove extends headwards over the embryonic area between the ectoderm and the primary entoderm. This invagination forms a relatively wide, flattened tube, lined by *secondary entoderm*, which corresponds to the chordal plate and the mesoderm in amphioxus. The primary entoderm in the roof of the digestive cavity and the floor of this secondary invagination break down so that the roof of the gut comes to be formed by the secondary entoderm in the roof of the invagination (fig. 85). The cells in the median plane of this new roof can now be identified as a 'chordal plate,' and the primary entoderm grows medially again towards this area. As it does so the lateral part of the secondary entoderm becomes shut out from the gut and lies as a solid plate between the primary entoderm and the ectoderm. It is now recognisable as a part of the intra-embryonic mesoderm and is continuous caudally with the cells of the primitive streak. Subsequently it loses its connexion with the chordal plate, which becomes excalated from the gut as the notochord.

If the earlier stages of the development of the human ovum be re-examined in the light of this summary it will be found that they recapitulate these changes, although the process has been so abbreviated as to obscure the resemblance. The whole of the holoblastic egg of amphioxus gives rise to the embryo. The human egg is also holoblastic, but the fact that only a small proportion of the cells to which it gives origin actually contribute to the formation of the embryo indicates that its holoblastic character is secondary and that it has evolved from an ancestral meroblastic stock. It is therefore necessary to compare it with the reptilian egg in the first place. The primitive node, which is a centre of intensely active growth in the embryos of birds and mammals, is pierced by the neurenteric canal. The node itself corresponds to the dorsal lip of the reptilian blastopore and the neurenteric canal to the blastopore itself. The notochord arises from the chordal plate, which forms the median part of the roof of the digestive cavity in amphioxus and in amphibians. In reptilia, however, it is derived from the secondary entoderm which arises as an outgrowth from the primitive streak, and secondarily becomes incorporated in the roof of the digestive cavity. Its origin in man is very similar to its origin in reptilia, although it arises as a solid rod, which later becomes canaliculised and associated with the roof of the gut, being temporarily included in it. The origin of the intra-embryonic mesoderm is closely allied to the origin of the notochord. In amphioxus it is involved in the process of gastrulation and lies in the dorsilateral wall of the archenteron in continuity with the chordal plate on the one hand and with the entoderm on the other (fig. 82, I); in amphibia it is an outgrowth from the sides of the chordal plate (gastral mesoderm), but at its caudal end it emerges into the primitive streak (prostomial mesoderm), a structure which can only occur in meroblastic ova. In reptilia the double origin of the mesoderm is again found, and in man the secondary (intra-embryonic) mesoderm, although mainly derived from the primitive streak, receives a contribution from the prochordal plate (p. 60)

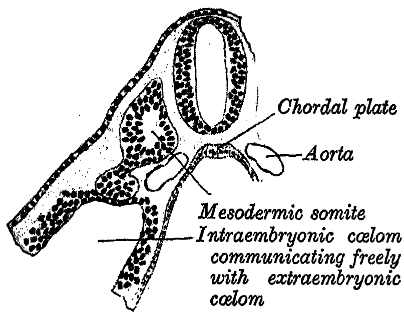
THE SEGMENTATION OF THE MESODERM AND THE FORMATION OF THE INTRA-EMBRYONIC CŒLOM

In the embryos of all vertebrate animals the intra-embryonic mesoderm becomes incompletely subdivided by a longitudinal groove into a *paraxial portion* and a *lateral plate*, on each side of the median plane. The mesoderm in the floor of the groove which connects these two portions is termed the *intermediate cell mass*, or *nephrogenic cord* (fig. 80). Soon after the appearance of this longitudinal groove the paraxial mesoderm becomes subdivided into a series of cubical blocks by a series of transverse grooves. This process is termed the *segmentation of the mesoderm*, and the blocks of paraxial mesoderm so formed are known as *mesodermic somites*, *primitive segments* or *metameres*. Commencing at the end of the third or the beginning of the fourth week in the region of the hind-brain the process extends in a caudal direction, additional somites being laid down as the embryo grows in length, until some thirty-five or more pairs are present (fig. 133). In the human embryo it is only the paraxial mesoderm which is actually segmented, but in view of the obviously segmental arrangement of the nerves of the spinal cord and their distribution, it is reasonable to suppose that the segmentation of the other structures is only obscured. The whole process may be regarded as evidence that the invertebrate ancestor of all vertebrate animals showed clear signs of its segmental origin.

Each mesodermic somite at first contains a central cavity termed the *myocoel*, which is soon filled by a core of spindle-shaped or fusiform cells. The cells occupying the dorsilateral portion of the somite constitute the *myotome*, and

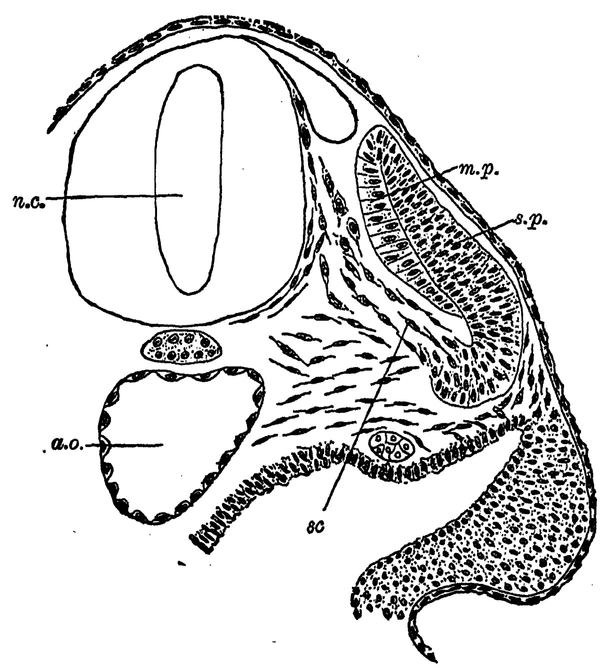
they are destined to give rise to a *muscle plate*, from which all the striated musculature of the segment is derived (p. 102). The cells occupying the ventrimedial portion of the somite are more loosely arranged and fusiform in shape. They constitute the *sclerotome* and give rise to the *scleratogenous tissue* from which the axial skeleton is ultimately derived (p. 83).

Fig. 86.—Cross-section through the body of a human embryo at the end of the fourth week, to show the arrangement of the mesoderm. Diagrammatic.



While the segmentation of the mesoderm is proceeding, a number of clefts appear in the lateral plate on each side. These clefts soon run into one another, and they extend headwards into the pericardial area (p. 59), where a cavity has already been formed. In this way the lateral plate becomes divided into a *somatic* and a *splanchnic layer* (fig. 80). The somatic layer, with its covering of ectoderm, constitutes the *somatopleure*, and the splanchnic layer, with the underlying entoderm, constitutes the *splanchnopleure*. The cavity which they include is termed the *intra-embryonic cœlom*, and from it the pericardial, pleural and peritoneal cavities are subsequently developed. Around the periphery of the embryonic area the somatopleure and the splanchnopleure are continuous, at first, both with each

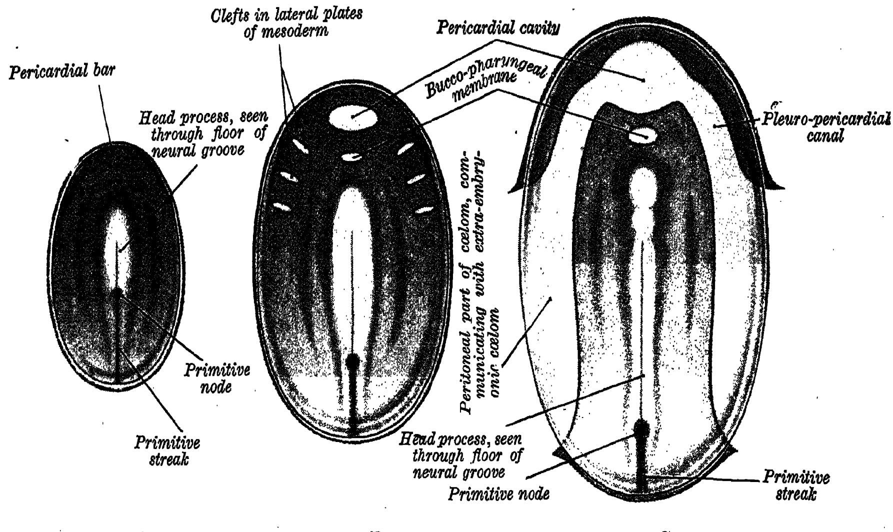
Fig. 87.—A transverse section of a human embryo of the fourth week, to show the differentiation of the primitive segment. (Kollmann.)



a.o. aorta; *m.p.* and *s.p.*, muscle-plate; *n.c.*, neural canal; *sc.*, sclerotome.

other and with the primary mesenchyme (fig. 80). Soon, however, the cleft extends beyond the embryonic area, the continuity between the somatopleure and the splanchnopleure is broken, and the intra-embryonic cœlom is thrown into free communication with the extra-embryonic cœlom. This process does not affect the pericardial area or the regions immediately adjoining it on either side; the latter constitute the pleuropericardial canals (fig. 88, C).

FIG. 88.—Diagram illustrating the formation of the cœlom.

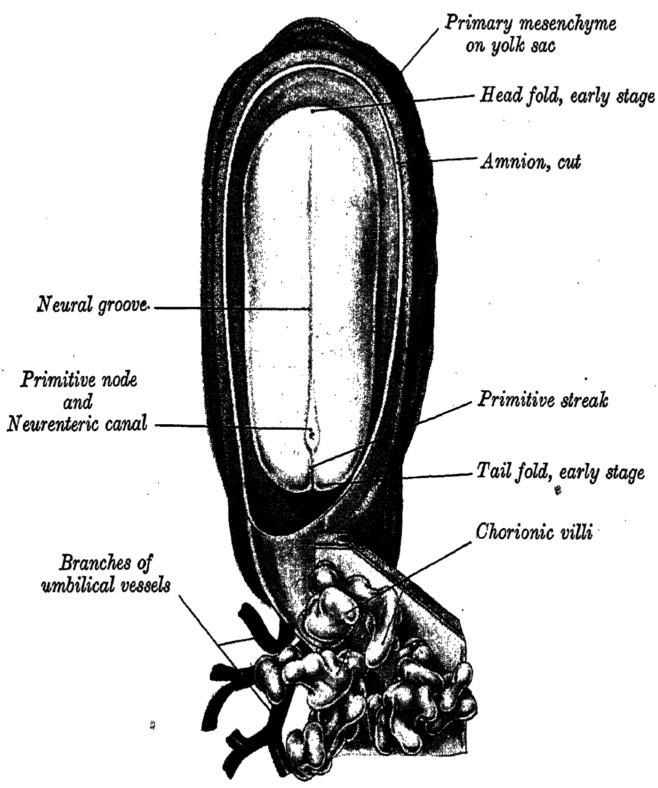


In A the secondary mesoderm (shown in blue) extends over the embryonic area and becomes continuous with the primary mesenchyme around the periphery. The median area, shown in yellow, represents the floor of the neural groove and is devoid of secondary mesoderm.

In B the pericardial cavity has appeared at the head end of the embryonic area and a series of clefts is present in the lateral plate on each side.

In C the clefts have extended and run into one another and into the pericardial cavity. In the caudal part of the area the clefts have broken through into the extra-embryonic cœlom.

FIG. 89.—Dorsal view of a human embryo, 1·3 mm. long. (From a model by Eternod.)



THE FORMATION OF THE EMBRYO

The formation of the head and tail folds.—Hitherto we have been dealing with a disc-like embryonic area, but at the end of the third week of its development the embryo begins to assume its definitive shape. The immediate cause of this alteration is the difference in the rate at which adjoining areas are growing. The rate of growth in the periphery of the embryonic area fails to keep pace with the rate of growth in the embryonic area, and, as the embryo is increasing more rapidly in its long axis, its cephalic and caudal extremities tend to bulge forwards and tailwards and so project beyond the limits of the area (figs. 93, A, and 95). In this way a *head-fold* is developed at the cephalic extremity and a *tail-fold* at the caudal extremity of the embryonic area. At the same time right and left *lateral folds* develop, and the extension of these four folds gradually constricts off the embryo from the yolk sac and gives it its characteristic shape.

Fig. 90.—A diagram showing one of the earliest observed stages of the human ovum.

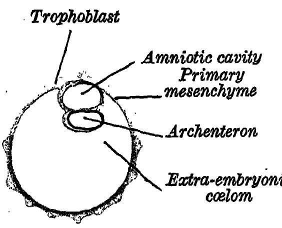


Fig. 91.—A diagram illustrating the early formation of the allanto-enteric diverticulum and the definition of the connecting stalk.

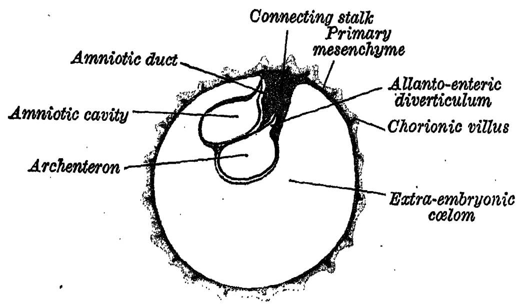
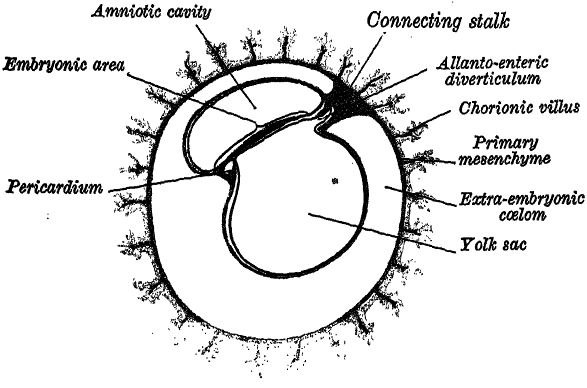


Fig. 92.—A diagram showing a later stage of the development of the human embryo. Observe that the heart occupies the most anterior part of the embryonic area and is separated from the prosencephalon by the buccopharyngeal membrane.



As a result of the formation of the head-fold, the prosencephalon, which was hitherto separated from the cephalic extremity of the embryonic area by the buccopharyngeal membrane and the pericardial area, comes to lie at the cephalic extremity of the embryo (figs. 93, A, 94). This alteration in position of

the fore-brain is accompanied by a corresponding alteration in the relative positions of the buccopharyngeal membrane and the pericardial area (figs. 172 and 174). The former now lies on the ventral surface and is situated at the bottom of a depression, which constitutes the primitive mouth or *stomodæum*. On its cephalic side the stomodæum is bounded by the projecting fore-brain and on its caudal side by the pericardial area. The latter has not only altered its

FIG. 93A.—A diagram showing the formation of the head- and tail-folds, the expansion of the amnion, and the delimitation of the umbilicus.

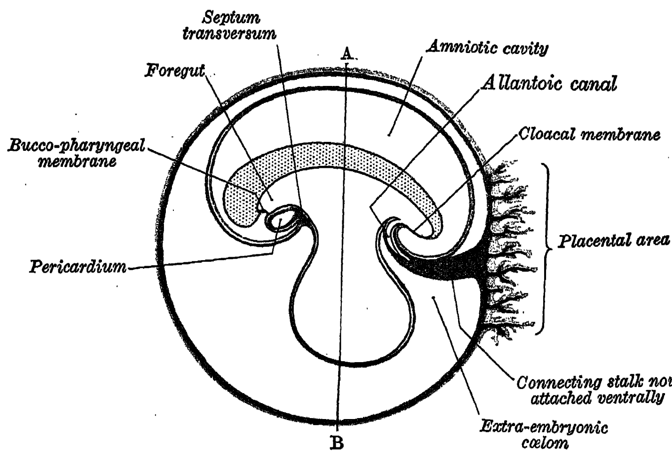
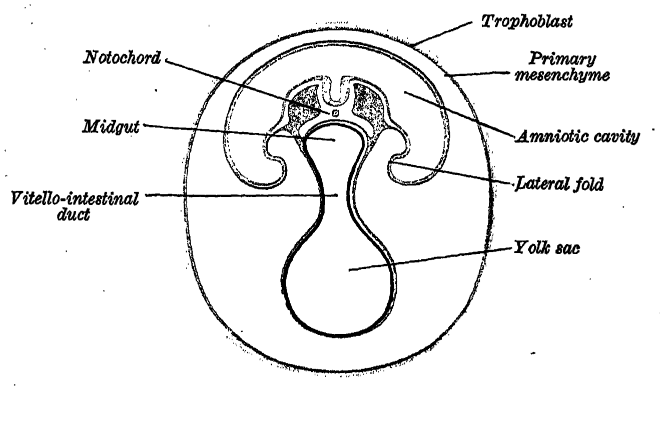


FIG. 93B.—A diagram showing a transverse section along the line AB in Fig. 93A. Observe that the intra-embryonic cœlom communicates freely with the extra-embryonic cœlom.



position relative to the cephalic extremity of the embryo but has also undergone a reversal of its surfaces, as will be pointed out later.

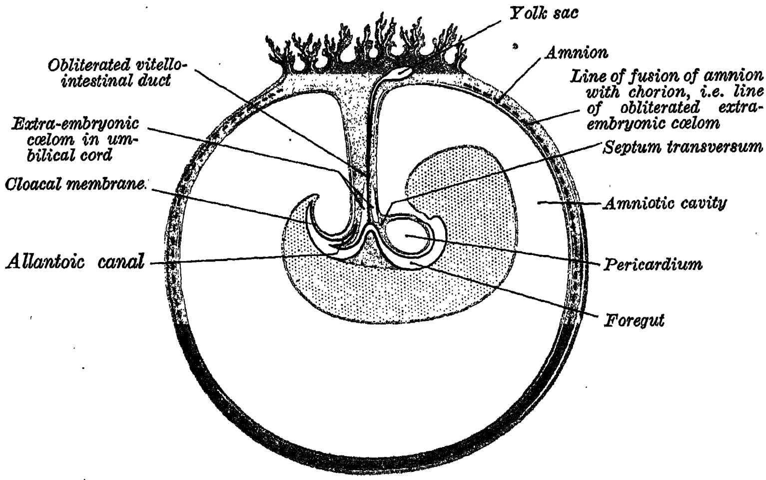
In addition to these alterations the head-fold results in the inclusion within it of a portion of the entodermal vesicle. This included portion is termed the *fore-gut* and it is placed between the buccopharyngeal membrane and the pericardium, on its ventral aspect, and the hind-brain, dorsally (fig. 94). It communicates at its caudal end with the midgut through an opening often termed the *anterior intestinal portal*.

The ventral bend of the head-fold produces a well-marked flexure in the brain at the site of the mesencephalon, termed the *cephalic flexure*.

Prior to the formation of the tail-fold the embryonic area is anchored to the trophoblast by a stalk of primary mesenchyme, covered on one aspect by

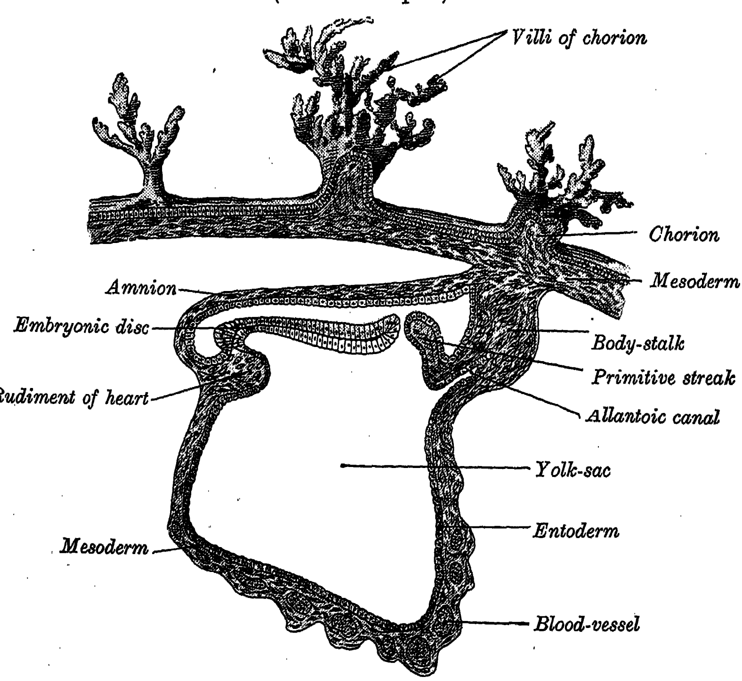
the epithelium of the amnion (fig. 92). This connexion, which is termed the *connecting stalk*, serves to conduct blood-vessels to the embryo from the chorion and vice-versa. The formation of the tail-fold carries the connecting stalk round

Fig. 94.—A diagram illustrating a later stage in the development of the umbilical cord.



on to the ventral aspect of the embryo, so that it now assumes the permanent position of the umbilical cord. It will be remembered that the stalk was connected to the embryo at the caudal end of the primitive streak, and, in

Fig. 95.—A sagittal section through the embryo which is represented in fig. 89. (After Graf Spee.)



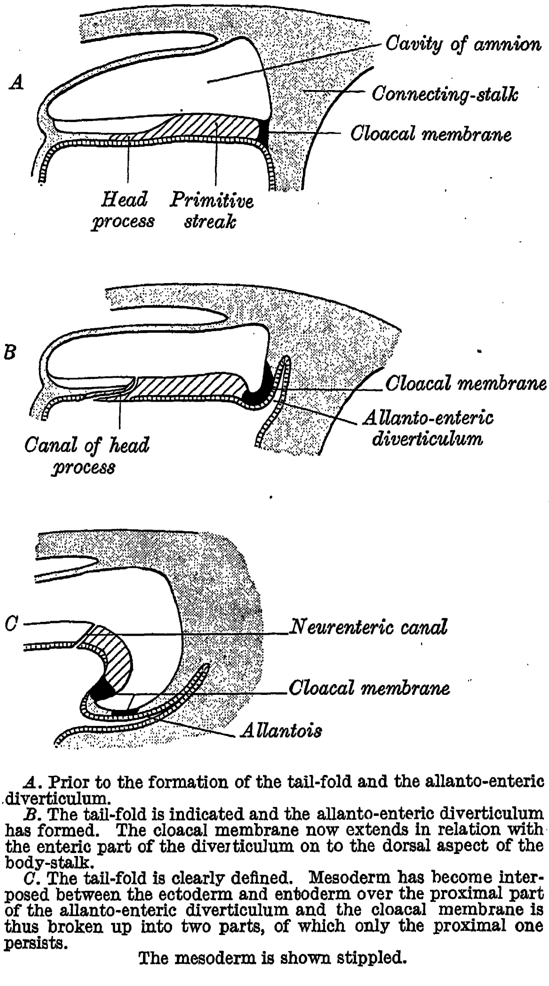
consequence of the formation of the tail-fold, the primitive streak like the connecting stalk extends round on to the ventral aspect of the embryo, traversing the region which will become the perineum.

Just as a portion of the entodermal vesicle is included within the head-fold

to form the fore-gut, so a corresponding portion is included within the tail-fold to form the *hind-gut.* But the similarity between these two included portions goes further. A portion of the entoderm in the floor or ventral wall of the fore-gut comes into direct contact with the ectoderm over an area which is termed the buccopharyngeal membrane. This membrane soon disappears and the communication of the gut with the exterior through the mouth is thus established. In the region of the hind-gut a similar relationship exists. Even before the tail-fold is defined, the ectoderm and entoderm come into contact with each other over a limited area at the caudal end of the embryonic area, forming the *cloacal membrane* (fig. 96, *A*). As will be described later, this membrane subsequently breaks down in two places to form the urogenital and anal orifices, which therefore lie in the line of the primitive streak.

Prior to the formation of the tail-fold a diverticulum arises from the dorsi-caudal portion of the archenteron and grows into the mesenchyme of the connecting stalk (fig. 91). This outgrowth constitutes the *allanto-enteric diverticulum* (fig. 96, *B*). As the tail-fold becomes defined the proximal part of the diverticulum becomes incorporated in the hind-gut, and its distal portion persists as the allantoic canal or *allantois* (p. 73), which then communicates directly with the ventral surface of the hind-gut. The portion of the hind-gut which lies caudal to this communication forms the *entodermal cloaca* (p. 171). As the tail-fold is formed, the cloacal membrane comes to lie in the ventral wall of the hind-gut but it extends also on to the adjoining dorsal aspect of the connecting stalk, where it is associated with the enteric portion of the allanto-enteric diverticulum (fig. 96, *B*). Even before the latter is incorporated in the hind-gut, the cloacal membrane becomes interrupted and shortened by the interposition of mesenchyme between the entoderm of the diverticulum and the ectoderm of the body-stalk * (fig. 96, *C*).

Fig. 96.—Three stages in the development of the cloacal membrane. (J. Florian.)



A. Prior to the formation of the tail-fold and the allanto-enteric diverticulum.
B. The tail-fold is indicated and the allanto-enteric diverticulum has formed. The cloacal membrane now extends in relation with the enteric part of the diverticulum on to the dorsal aspect of the body-stalk.
C. The tail-fold is clearly defined. Mesoderm has become interposed between the ectoderm and entoderm over the proximal part of the allanto-enteric diverticulum and the cloacal membrane is thus broken up into two parts, of which only the proximal one persists.

The mesoderm is shown stippled.

Between the head- and the tail-folds the embryo becomes constricted off by right and left lateral folds. The intervening dorsal portion of the entodermal vesicle, which these folds threaten to cut off, and later succeed in separating from the remainder of the vesicle, constitutes the *mid-gut.* At first the mid-gut communicates freely on its ventral surface with the rest of the entodermal vesicle, but the continued growth of the folds results in a narrowing of the connexion, which becomes drawn out as the *vitello-intestinal duct* (figs. 93,

* J. Florian, *Journal of Anatomy,* vol. lxiv. July, 1930.

94). The remainder of the vesicle remains extra-embryonic and constitutes the *yolk-sac* or *umbilical vesicle*. The subsequent history of the duct and the vesicle will be dealt with later (pp. 168, 173).

The nutrition of the embryo.—In the early stages of development the cells of the ovum derive their nourishment from the store laid up within the cell body of the primary oöcyte. It is probable that this nourishment is at first maintained in a highly concentrated form and is subsequently liberated in a more dilute form, readily available for absorption, in the magma cavity of the blastocyst, and also, possibly, in the entodermal vesicle. In addition, it has been suggested that the blastocyst derives nourishment from the uterine glands and, during the process of imbedding, from the portion of the uterine wall which has been destroyed. Owing, however, to the relatively small amount of yolk contained in the human ovum, it is essential that some other source of food-supply should be rendered available at an early stage. The maternal circulation is selected, but it can only function as a source of supply when it is brought into close, though indirect, contact with the embryonic circulation. On this account, the formation of angioblastic tissue is very precocious in the human embryo.

The work of van der Stricht, Sabin and others makes it highly probable that the earliest angioblastic tissue is formed in the deepest part of the mesenchyme covering the entodermal vesicle or yolk-sac. About the same time, or slightly later, angioblastic tissue can be recognised in the connecting stalk and in the primary mesenchyme of the chorion, and a little later it appears also in the embryonic area. Tissue spaces form in the angioblast and the cells which line these spaces take on the characters of typical, flattened endothelial cells, and adjoining spaces run into one another and form a capillary plexus. While the spaces are in process of formation small, localised groups of mesodermal cells project into their interior and become cut off to form blood islets. The constituent cells of these islets become modified to form the blood corpuscles (p. 133).

The vessels formed in the chorion soon establish an intimate relationship with the maternal circulation (p. 77). The vessels which develop in the embryonic area form two longitudinal channels, which, at their headward ends, project into the dorsal wall of the pericardium. They are the rudimentary right and left dorsal aortæ, and at their cephalic ends, after curving ventrally on the lateral wall of the pharynx to reach the cephalic end of the pericardium, they fuse to form a primitive tubular heart. At the caudal end of the embryo they traverse the connecting stalk as the rudimentary umbilical arteries and break up into capillaries in the chorion. The venules from the chorion converge on the stalk where they form the right and left umbilical veins, which run headwards in the somatopleure, close to the margin of the embryonic area, to reach the heart.

It will be remembered that the pericardial cavity never communicates directly with the extra-embryonic cœlom, and at its cephalic limit the somatopleure and splanchnopleure become continuous (fig. 172). With the formation of the head-fold the surfaces of the pericardium are reversed, and the original cephalic limit comes to lie in intimate relation with the wall of the fore-gut at the ventral border of the anterior intestinal portal (fig. 174). As the floor (caudal limit) of the pericardium deepens ventridorsally, the mesenchyme between it and the gut forms a sheet which is termed the *septum transversum*. This structure later plays an important part in the development of the diaphragm ; at this stage it is bounded on its headward surface by the pericardium and on its caudal surface by the fore-gut, and on its lateral surfaces it is limited by the pleuropericardial canals, which connect the pericardium with the peritoneal cavity. The umbilical and body-wall veins, which run in the somatopleure, and the vitelline veins, which run in the splanchnopleure, meet one another in the septum transversum and so gain the venous end of the heart.

In this way there is established the circulation, through the vessels and tissues of the embryo, of blood which has derived oxygen and nutriment from the maternal circulation.

THE FŒTAL MEMBRANES AND THE PLACENTA

The **allantois** (figs. 91, 96).—The allanto-enteric diverticulum arises early in the third week as a solid, entodermal outgrowth from the dorsi-caudal part of the entodermal vesicle and grows into the primary mesenchyme of the connecting stalk. It soon becomes canaliculised and when the hind-gut is developed, the proximal (enteric) part of the diverticulum is incorporated in its ventral wall and the distal (allantoic) portion is carried ventrally to open into the ventral aspect of the cloaca or terminal part of the hind-gut. The allantoic diverticulum is lined with entoderm and is surrounded by the mesenchyme of the connecting stalk, in which the umbilical vessels develop at a slightly later stage.*

The **amnion** is a membranous sac which surrounds and protects the embryo ; it is developed in reptiles, birds, and mammals, but not in amphibia or fishes.

In the human embryo the earliest stages of the formation of the amnion have not been observed ; in the youngest embryo which has been studied † the amnion was already present as a closed sac, and, as indicated on page 54, it appears as a cavity in the ectodermal part of the inner cell-mass. This cavity is roofed in by a stratum of flattened ectodermal cells termed the *amniotic ectoderm,* and its floor consists of the prismatic ectoderm of the embryonic disc —the continuity between the roof and floor being established at the margin of the embryonic disc. On the outside the amniotic ectoderm is covered with a thin layer of primary mesenchyme which is continuous, round the margins of the embryonic disc, both with the primary mesenchyme covering the entodermal vesicle and with the intra-embryonic mesoderm. Through the medium of the connecting stalk it is continuous also with the mesenchyme lining the chorion (fig. 92).

Fluid, termed *liquor amnii,* appears within the amniotic cavity and increases steadily in amount, so that the sac gradually expands and encroaches on the cavity of the extra-embryonic cœlom (fig. 94) ; this expansion continues until the extra-embryonic cœlom is obliterated entirely, except for a small portion which is included within the umbilical cord. The liquor amnii increases in quantity up to the sixth or seventh month of pregnancy, and then diminishes somewhat ; at the end of pregnancy it amounts to 1 litre. It allows of the free movements of the fœtus during the later stages of pregnancy, and also diminishes the risk to the fœtus of injury from without. It contains less than two per cent. of solids, consisting of urea and other extractives, inorganic salts, a small amount of protein, and frequently a trace of sugar.

The **connecting stalk** and the **umbilical cord.**—The connecting stalk (figs. 92, 93, 94) is a mass of primary mesenchyme which at first connects the tail-end of the embryonic area with the chorion. Its proximal part surrounds the allanto-enteric diverticulum and it is traversed by the umbilical vessels. Its dorsal surface is covered with the amnion and its ventral surface is bounded by the extra-embryonic cœlom. As a result of the folding of the embryo and the distension of the amnion the connecting stalk comes to lie on the ventral surface of the embryo,

* In reptiles, birds, and many mammals the allantoic diverticulum expands into a vesicle which projects into the extra-embryonic cœlom and forms a vascular organ to which the term *allantois* should be restricted. In the bird it projects to the right side of the embryo, and, gradually expanding, spreads over the dorsal surface of the embryo as a flattened sac between the amnion and the serosa, and ultimately surrounds the yolk. Its outer wall becomes applied to, and fuses with, the serosa which lies immediately inside the shell membrane. Blood is carried to the allantoic sac by the two allantoic or umbilical arteries, which are continuous with the primitive aortæ, and after circulating through the allantoic capillaries, is returned to the primitive heart by the two umbilical veins. In this way the allantoic circulation, which is of the utmost importance in connexion with the respiration and nutrition of the chick, is established. Oxygen is taken from, and carbonic acid is given up to the atmosphere through the egg-shell, and nutritive materials are at the same time absorbed by the blood from the yolk. With the formation of the amnion the embryo is, in most animals, separated entirely from the chorion, and is not united to the chorion again until the allantoic mesenchyme spreads over and becomes applied to its inner surface ; but the human embryo, as was pointed out by His, is never wholly separated from the chorion, its tail-end being from the first connected with the chorion by means of a thick band of mesenchyme, named the *connecting stalk.*

† H. Stieve, *loc. cit.*, p. 55.

and its mesenchyme approaches that of the yolk-sac and vitello-intestinal duct (fig. 93).

As a consequence of the continued expansion of the amnion the extra-embryonic cœlom is obliterated to a very large extent (fig. 94), and the only part of it which remains surrounds the elongated vitello-intestinal duct, and

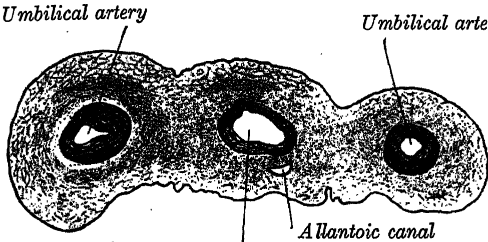
FIG. 97.—A fœtus of about eight weeks, enclosed in the amnion. Magnified a little over 2 diameters. Drawn from stereoscopic photographs lent by Prof. A. Thomson, Oxford.

still communicates freely with the intra-embryonic cœlom. The mesenchyme-covered surfaces of the head, tail and lateral folds of the amnion converge on the region of the connecting stalk and the vitello-intestinal duct, and the umbilical cord is formed as they meet one another (figs. 92, 94). The cord consists of an outer covering of amniotic ectoderm, containing in its interior the vitello-intestinal duct and the yolk-sac or umbilical vesicle, partially invested by the remains of the extra-embryonic cœlom and all imbedded in a mass of primary mesenchyme, contributed in part by the head and the lateral folds but, to a much greater extent, by the connecting stalk. The umbilical cord, therefore, incorporates within itself the connecting stalk and its contained umbilical vessels and the allantoic canal. The part of the extra-embryonic cœlom included in the umbilical cord acts as the sac for the normal umbilical hernia which characterises the embryo between the sixth and the tenth weeks (p. 168). After the disappearance of this hernia the remains of the extra-embryonic cœlom normally become obliterated.

The umbilical cord becomes spirally twisted, owing, it is believed, to the unequal growth of the two umbilical arteries; it also increases in length so that at the end of pregnancy it is about 50 cm. long.

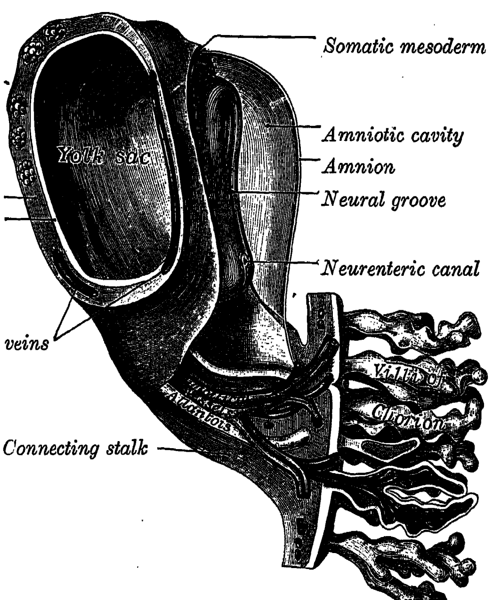
The implantation or imbedding of the fertilised ovum in the uterine wall.—As already stated (p. 51), fertilisation of the ovum is believed to occur in the lateral or ampullary end of the uterine tube, and is immediately followed by segmentation. The segmenting ovum is conveyed along the uterine tube to the cavity

FIG. 98.—A transverse section through the umbilical cord.



of the uterus by the action of the cilia of the epithelial lining of the tube, the journey occupying not less than three and not more than seven or eight days. By the time it reaches the uterus it possesses a well-developed trophoblast, which adheres like a parasite to the uterine mucous membrane, destroys the epithelium over the area of contact, and excavates for the ovum a cavity in the mucous membrane in which it becomes imbedded. In an ovum described

FIG. 99.—A human embryo, 1·3 mm. long. (From a model by Eternod.)



by Bryce and Teacher * the point of entrance of the ovum into the uterine mucous membrane was visible as a small gap closed by a mass of fibrin and leucocytes (fig. 74) ; in an ovum described by Peters † the opening was covered with a mushroom-shaped mass of fibrin and blood-clot, the narrow stalk of which plugged the aperture in the mucous membrane. It is believed that this operculum represents a portion of the plasmodial trophoblast of the ovum which is cut off by the decidua capsularis (*vide infra*).

* Contribution to the study of the early development and imbedding of the human ovum, 1908.

† *Die Einbettung des menschlichen Eies,* 1899.

The structure actively concerned in excavating the uterine mucous membrane is the plasmodial trophoblast. This increases rapidly in thickness, invades and digests the uterine tissues, and attacks the walls of the uterine (maternal)

Fig. 100.—Primary chorionic villi. Diagrammatic. (Modified from Bryce.)

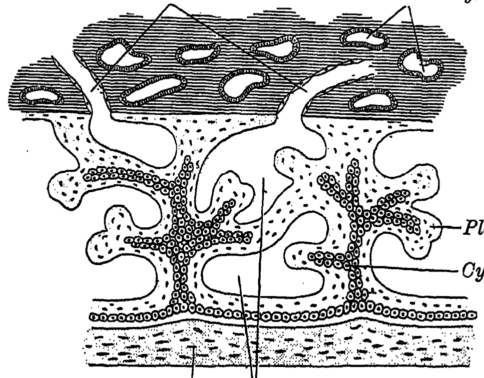


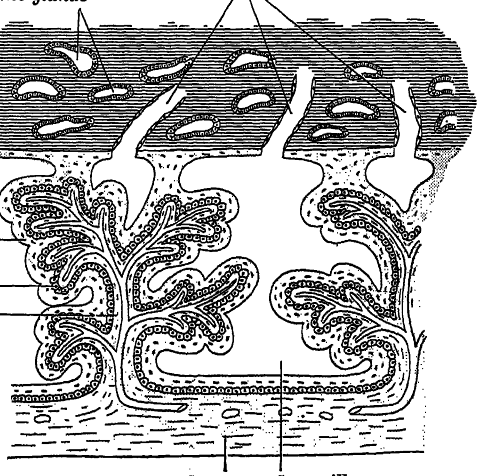
Fig. 101.—A secondary chorionic villus. Drawn from a microphotograph.

blood-vessels (fig. 74). This trophoblastic envelope soon becomes converted into a loose spongework, containing anastomosing spaces filled with maternal blood from the dilated uterine veins and capillaries, the walls of which have been partially destroyed. The strands of trophoblast which constitute the spongework are termed *primary villi.** The blood spaces expand to form what is ultimately known as the *intervillous space*. The inner wall of this space is formed by the chorion and its outer wall is formed by a shell of trophoblast (fig. 101). The primary villi become replaced by *secondary villi*, which contain

* The classification of the villi adopted here is that suggested by H. Stieve, *loc. cit.* p. 55.

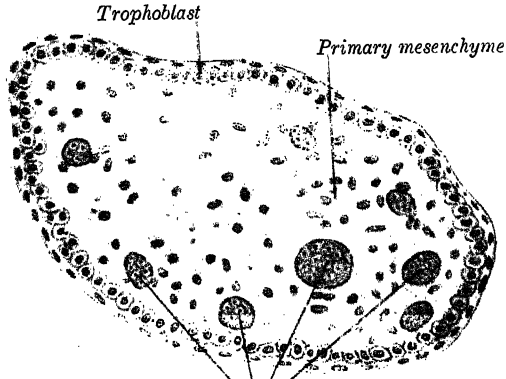
an inner core of primary mesenchyme derived from and continuous with the mesenchyme of the chorion. This core is covered by a single layer of cytotrophoblast, which in turn is covered by a layer of plasmodial trophoblast. The

FIG. 102.—Tertiary chorionic villi. Diagrammatic. (Modified from Bryce.)



secondary villi give off numerous branches and at their outer ends their cytotrophoblast becomes continuous with the cytotrophoblast of the trophoblastic shell. The shell consists for the most part of cytotrophoblast, but it is covered on its

FIG. 103.—A transverse section of a tertiary chorionic villus.



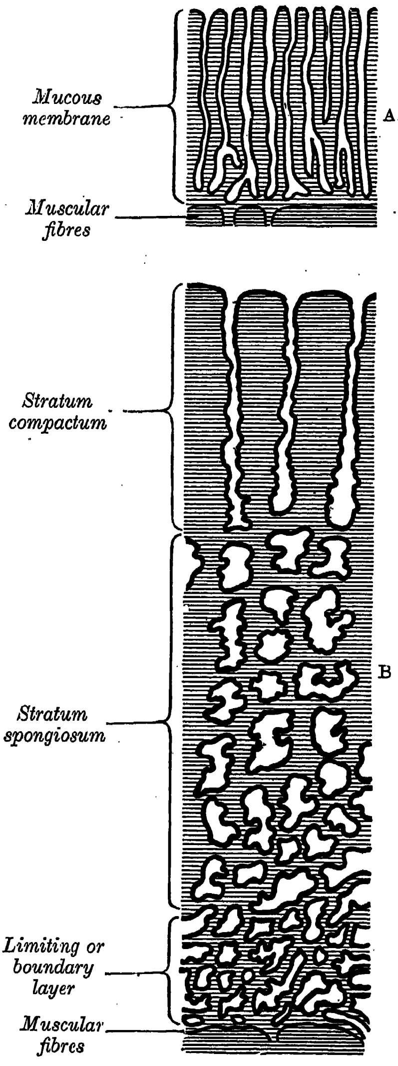
inner surface by plasmodium. As a result the blood-bathed walls of the intervillous space and of the villi are everywhere formed of plasmodial trophoblast. Finally, the secondary villi are converted into *tertiary villi* by the development within them of vascular spaces which soon become linked up with the radicles of the umbilical vessels. Through the walls of these villi and of their contained capillaries nutriment and oxygen pass to the fœtal circulation from the maternal blood in the intervillous space.

The plasmodial trophoblast which lines the intervillous space has been termed *resorptive trophoblast*,* as it is the medium by which nourishment is obtained for the ovum from the maternal circulation. Plasmodial trophoblast

* J. Florian, *Ergänzungsheft z. Anat. Anzeiger*, Bd. 66.

is found in other situations also, and especially around the periphery of the ovum where actively growing strands of plasmodium are responsible for the destruction of the uterine tissues. This variety is termed *proliferative trophoblast*, and its function is to enlarge the bed in which the ovum lies so as to provide for its increase in size. Wherever these strands of proliferative trophoblast break through the wall of a uterine blood-vessel and come into contact with the blood-stream, they tend to change their character and become transformed into the more passive resorptive variety.

FIG. 104.—Sections of the uterine mucous membrane; (A) of the non-pregnant uterus; (B) of the pregnant uterus. Diagrammatic. (Kundrat and Engelmann.)



The **decidua.** Before the fertilised ovum reaches the uterus, the mucous membrane of the body of the uterus undergoes important changes, and is then known as the *decidua*. The thickness and vascularity of the mucous membrane are greatly increased; its glands are elongated and their deeper portions are tortuous and dilated into irregular spaces. The interglandular tissue is increased in quantity; it contains a number of leucocytes, and is crowded with large round, oval, or polygonal cells, termed *decidual cells*. These changes are well advanced by the second month of pregnancy, when the mucous membrane consists of the following strata (fig. 104): (1) *stratum compactum*, next the free surface; in this the uterine glands are only slightly expanded, and are lined with columnar cells; (2) *stratum spongiosum*, where the uterine glands are greatly dilated and very tortuous, and are ultimately separated from one another by a small amount of interglandular tissue; for a time the cells lining the glands are cylindrical, but later they become flattened; (3) a thin *limiting or boundary layer*, next the uterine muscular fibres, containing the deepest parts of the uterine glands, which are not dilated, and are lined with cubical epithelium; it is from this epithelium that the epithelial lining of the uterus is regenerated after parturition.

After the ovum is imbedded distinctive names are applied to different portions of the decidua. The part which covers the ovum is named the *decidua capsularis*; the portion between the ovum and the uterine muscular wall is named the *decidua basalis*, and it is here that the placenta is subsequently developed; the part which lines the remainder of the body of the uterus is known as the *decidua parietalis* (fig. 106.).

Coincidently with the growth of the embryo, the decidua capsularis is thinned and distended (figs. 105, 106) and the space between it and the decidua parietalis is gradually obliterated. By the beginning of the third month of pregnancy the decidua capsularis and decidua parietalis are in contact; by the fifth month the decidua capsularis has practically disappeared, while during the succeeding months the decidua parietalis also atrophies, owing to the increased pressure. The glands of the stratum compactum are obliterated, and their epithelium is lost; in the stratum spongiosum the glands are compressed

and appear as slit-like fissures, and their epithelium undergoes degeneration ; in the limiting or boundary layer, however, the glandular epithelium retains a cubical form.

The **chorion** (figs. 89 to 94 and 100 to 102) consists of two layers : an outer of trophoblast, and an inner of primary mesenchyme. The trophoblast consists of an internal layer, termed the *cytotrophoblast*, and an external layer, termed the *plasmodial trophoblast*. As stated (p. 53), the trophoblast undergoes rapid proliferation and forms, on the surface of the chorion, a succession of processes which are known as the *primary*, *secondary* and *tertiary chorionic villi* (fig. 101). Blood is carried from the embryo to the chorion by the umbilical arteries, and after circulating through the capillaries of the chorionic villi, is returned to the embryo by the umbilical veins. Until about the end of the second month of pregnancy the entire chorion is covered with villi, which are almost uniform in size, and project into the decidua basalis and decidua capsularis (fig. 106). With the growth of the embryo and the expansion of the amniotic cavity the decidua capsularis is thinned and compressed, the circulation through it is gradually cut off, and the villi of the corresponding part of the chorion atrophy and disappear. This portion of the chorion becomes smooth (*chorion læve*) ; and, as it takes no share in the formation of the placenta, is sometimes named the non-

FIG. 105.—Diagram showing a young ovum imbedded in the uterine decidua near the fundus.

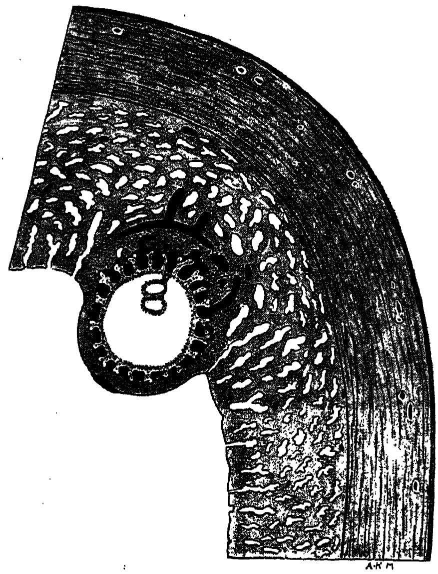
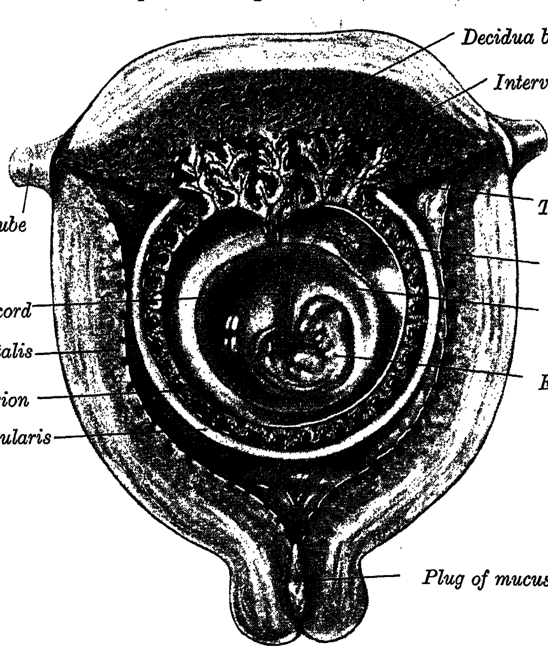


FIG. 106.—A sectional plan of the gravid uterus in the second month.

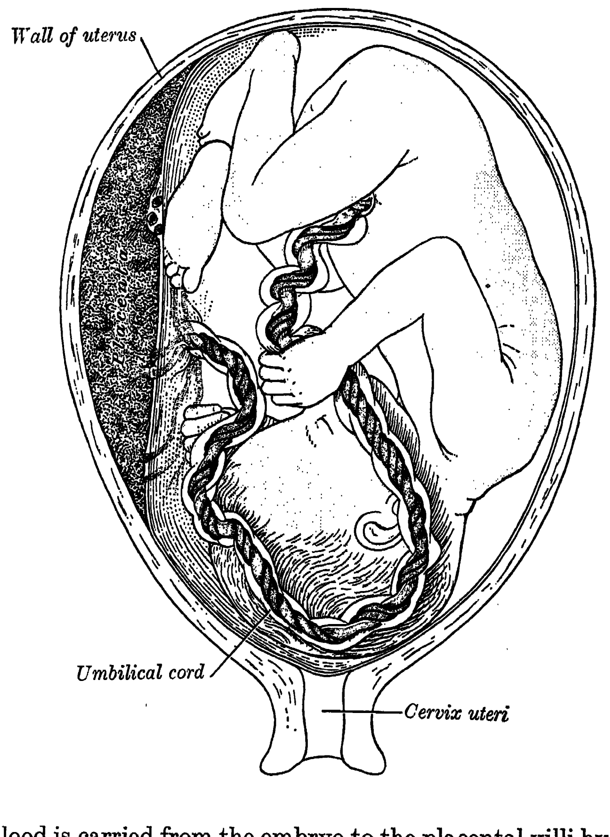


placental part of the chorion. On the other hand, the villi on that part of the chorion which is in contact with the decidua basalis increase greatly in size and complexity, and hence this part is named the *chorion frondosum* (figs. 93A, 94).

The **placenta** (figs. 106 to 108) connects the fœtus to the uterine wall, and is the organ by means of which the nutritive, respiratory, and excretory functions of the fœtus are carried on. It is composed of fœtal and maternal parts.

The *fœtal portion of the placenta* consists of the villi of the chorion frondosum, which branch repeatedly and increase enormously in size. The ends of some of the villi are anchored by columns of trophoblast to the walls of the intervillous space, but the majority hang free in the space. All are bathed in maternal blood, which is conveyed to and from the intervillous space by the uterine

Fig. 107.—A fœtus in utero, between the fifth and sixth months.

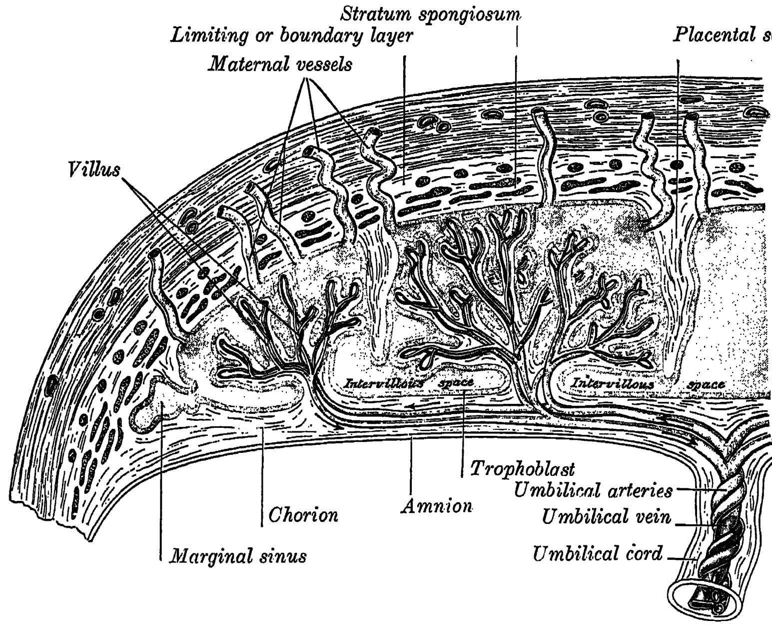


vessels. Blood is carried from the embryo to the placental villi by the umbilical arteries, and returned to the embryo by the umbilical veins. One or two branches of an artery enter each villus and there end in a capillary plexus, which is drained by one or two tributaries of the veins. The vessels of the villi are surrounded by a thin layer of mesenchyme, which is covered with the two strata of the trophoblast, the cytotrophoblast being in contact with the mesenchyme, and the plasmodial trophoblast in contact with the maternal blood (fig. 102); after the fifth month the two strata are replaced by a single layer of somewhat flattened cells.

The *maternal portion of the placenta* is formed by the decidua placentalis containing the intervillous space. As already explained (p. 76), this space is produced by the enlargement and intercommunication of the spaces in the trophoblast; it is therefore lined throughout with plasmodial trophoblast. The formation of the intervillous space involves the disappearance of the greater portion of the stratum compactum, but the deeper part of this layer persists and is condensed to form what is known as the *basal plate*; this constitutes the outer wall of the intervillous space, and consists of a stroma containing decidual

cells, portions of trophoblast and *fibrinoid substance*; the last appears to be derived in part from the trophoblast and in part from the maternal blood. The interval between the basal plate and the uterine muscular fibres is occupied by the stratum spongiosum and the limiting layer; through these and the basal plate the uterine arteries and veins pass to and from the intervillous space. Portions of the stratum compactum persist as pillars which project into the intervillous space, but these pillars do not extend as far as the chorion, except in the marginal part of the placenta; later they form the *placental septa* which incompletely divide the placenta into lobes or *cotyledons*.

Fig. 108.—A scheme of the placental circulation.



Maternal blood is conveyed to the intervillous space by branches of the uterine arteries and carried away by tributaries of the uterine veins (figs. 107, 108). These vessels lose their muscular coats as they enter the basal plate, and in this plate consist of sinuous channels lined only with endothelium; these channels open into the intervillous space, the arteries ending near the placental septa and the veins beginning near the centres of the cotyledons. The endothelial lining of the uterine vessels ends where the vessels open into the intervillous space, the latter being lined throughout with plasmodial trophoblast. The circumferential part of the intervillous space consists of an irregular channel named the *marginal sinus* (fig. 108); this sinus partly encircles the placenta and communicates peripherally with the uterine veins, and centrally with the intervillous space; clusters of placental villi project into it.

The fœtal and maternal blood-currents do not intermingle, being separated from each other by the delicate walls of the villi. Nevertheless, the fœtal blood is able to absorb, through the walls of the villi, oxygen and nutritive materials from the maternal blood, and to give up to the latter its waste products. The blood, so purified, is carried back to the fœtus by the umbilical veins. It will thus be seen that the placenta not only establishes a mechanical connexion between the mother and the fœtus, but subserves for the latter the purposes of nutrition, respiration, and excretion. That the placenta possesses certain selective powers is evidenced by the fact that glucose is more plentiful in the maternal than in the fœtal blood; it is interesting to note also that the proportion of iron, lime and potash in the fœtus is increased during the last months of pregnancy. Further, there is evidence that the maternal leucocytes may

migrate into the fœtal blood, since leucocytes are much more numerous in the blood of the umbilical vein than in that of the umbilical arteries.

Applied Anatomy.—The placenta is usually attached near the fundus uteri, and its site corresponds with that at which the ovum is imbedded. It may, however, occupy a lower level, and in very rare cases occludes the internal orifice of the uterus, thus giving rise to the condition known as *placenta prævia.*

The *separation of the placenta.*—After the child is born, the placenta and membranes (the latter consisting of the amnion, the chorion læve and the superficial part of the decidua parietalis) are separated from the uterine wall and expelled as the *after-birth.* The separation takes place along the plane of the stratum spongiosum (fig. 108), and necessarily causes rupture of the uterine vessels. The orifices of the torn vessels are, however, closed by the firm contraction of the uterine muscular fibres, and thus *post-partum hæmorrhage* is prevented. After the separation of the placenta and membranes a thin layer of the stratum spongiosum is left as a lining to the uterus, but this layer subsequently undergoes degeneration, and is cast off. The mucous membrane, the glands and the epithelial lining of the uterus are regenerated from the limiting or boundary layer of the decidua (p. 78).

The expelled placenta is a discoid mass which has a weight of about 500 gm., a diameter of from 15 cm. to 20 cm., and an average thickness of about 3 cm., but the thickness rapidly diminishes near the circumference of the placenta, which is continuous with the membranes. Its uterine or outer surface is divided by a series of fissures into lobules or *cotyledons* which are imperfectly separated from one another by the placental septa. Its fœtal or inner surface is smooth, and is closely invested by the amnion. When looked at through the amnion, the chorion presents a mottled appearance, consisting of grey, purple, or yellowish areas. The umbilical cord is usually attached near the centre of the fœtal surface of the placenta, but may be inserted at any point between the centre and the margin; in some cases it is inserted into the membranes, i.e. the *velamentous* insertion. From the site of the attachment of the cord the larger branches of the umbilical vessels radiate under the amnion, the veins being deeper and larger than the arteries. Beneath the amnion, close to the cord, the remains of the vitello-intestinal duct and yolk-sac are sometimes seen, the former as an attenuated thread, the latter as a minute sac.

On section, the placenta presents a soft, spongy appearance, caused by the greatly branched villi; these are surrounded by a varying amount of maternal blood, which gives the structure its characteristic dark red colour.

THE DEVELOPMENT OF THE INDIVIDUAL SYSTEMS

The development of the embryo has already been traced to a stage at which the process of differentiation becomes so complicated that it is no longer possible to deal with the embryo as a whole. At this stage the embryo is only partly constricted off from the entodermal vesicle. The head- and tail-folds have formed, with the resultant enclosure of the fore-gut and the hind-gut. The projection caused by the fore-brain is now the cephalic end of the embryo, and the buccopharyngeal membrane and the pericardium lie caudal to it on the ventral aspect. The secondary mesoderm has differentiated to a certain extent, and its paraxial portion is undergoing segmentation with the resultant formation of mesodermic somites. The neural groove is in process of closure to form the neural tube and it is separated from the dorsal wall of the gut by the notochord. The earliest blood-vessels have been laid down and a primitive tubular heart is present in the pericardium. The chorionic circulation has been established and the embryo derives the nourishment which it requires from the maternal blood. The intra-embryonic cœlom consists of the pericardial cavity, from the dorsal aspect of which right and left pleuro-pericardial canals lead tailwards and, caudal to the septum transversum, communicate freely with the peritoneal cavity and with the extra-embryonic cœlom (fig. 88).

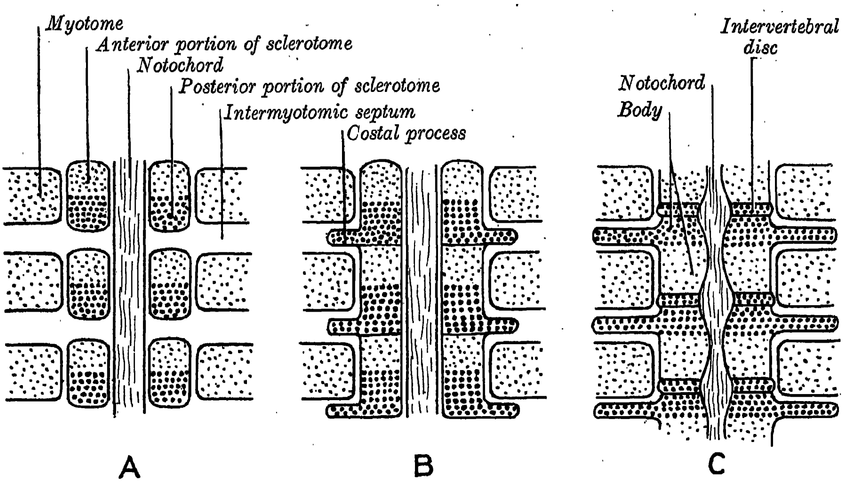
It is now necessary to deal with the development of the various systems and organs independently of one another, but, in the pages that follow, it will frequently be necessary to refer back to the stage which has just been summarised.

THE DEVELOPMENT OF THE SKELETAL SYSTEM

The skeleton is of mesodermal origin, and most of its parts pass through, first, a membranous or mesenchymal stage, and then a cartilaginous stage before they become ossified. In many instances the process of ossification follows immediately on the membranous stage, and the stage of chondrification is omitted.

The **vertebral column.**—Before it reaches its final condition the central axis of the body passes through no fewer than three preliminary stages. In the first place it is formed by the non-segmented notochord (p. 59), a flexible rod of cells enclosed within a stout membranous sheath. This structure, however, is not limited to the region in which the vertebral column is laid down, but extends into the region of the head as far as the caudal aspect of the hypophysis cerebri, and is subsequently incorporated in the basilar portion of the occipital bone and the posterior part of the body of the sphenoid.

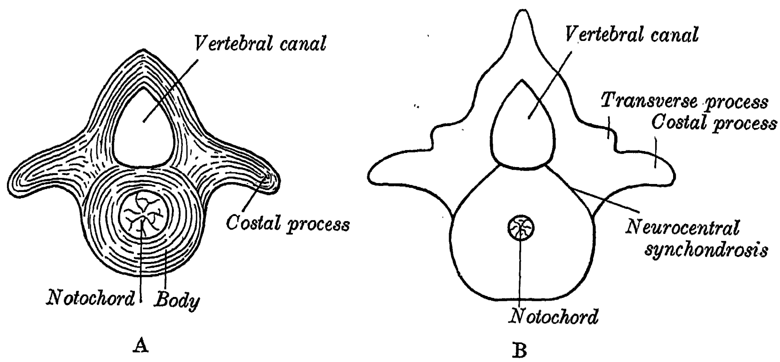
FIG. 109.—A scheme showing the manner in which each vertebral body is developed from portions of two adjacent segments.



The notochord acts as a framework around which the scleratogenous tissue derived from the sclerotomes (p. 66) builds up a *blastemal* or *mesenchymal vertebral column*, consisting of thirty-five or more segmental units, which are termed *protovertebræ*. Fusiform cells from the sclerotomes migrate ventrally and medially on each side and enclose the notochord in a mass of mesenchyme, which outlines the vertebral centrum (fig. 87). Coronal or sagittal sections passing through the blastemal column show that the cells are more closely packed together in the caudal half of each protovertebra and more loosely arranged in its cephalic half (fig. 109). From the darker, caudal portion of the protovertebra an extension grows dorsally on each side of the neural tube to outline the neural arch, and another extension grows laterally into the interval between the corresponding myotome and the one caudal to it, to outline the costal process. While these extensions are appearing, the darker caudal half of each protovertebral centrum fuses with the lighter, cephalic half of the one caudal to it. In this way the segmental protovertebræ give place to *blastemal vertebræ*, each of which is formed from portions of two adjoining segments and retains connexion with the lateral and dorsal outgrowths from its cephalic half.

As no further change in position occurs during the ensuing periods of chondrification and ossification, it follows that the intervertebral discs of the adult are segmental in origin, whereas the vertebral bodies comprise portions of two adjoining segments and the intersegmental tissue between. The intersegmental vessels, which lay opposite the intervals between the protovertebræ, now lie

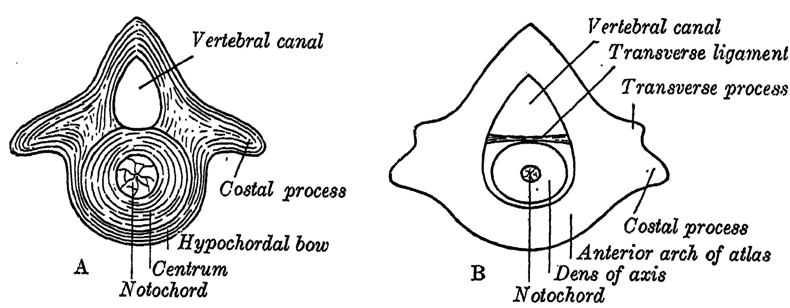
FIG. 110.—Diagrams showing (A) the blastemal and (B) the cartilaginous stages of a typical vertebra.



opposite the vertebræ, a topographical relationship which persists in the adult in the lumbar and lower thoracic regions.

The third stage in the development of the central axis of the body commences in the seventh week with the appearance of centres of *chondrification* in the blastemal vertebræ and their neural arches and proceeds to the formation of a *cartilaginous vertebral column.* Two centres of chondrification appear in the caudal half of each blastemal vertebra and fuse to form the cartilaginous *centrum.* Independent centres appear in each half of the neural arch and in each costal process. In the former chondrification extends forwards into the pedicles and backwards into the laminæ, but the two laminæ do not meet and fuse with one another until the fourth month of intra-uterine life. The centre

FIG. 111.—Diagrams showing the transformation of the hypochordal bow into the anterior arch of the atlas.



of chondrification in the costal process extends both laterally and medially and soon fuses temporarily with the centrum of the vertebra. This continuity does not last long and disappears as the costocentral joint becomes defined. Later, chondrification extends laterally from the neural arch to outline the transverse process, which lies dorsal to the costal process.

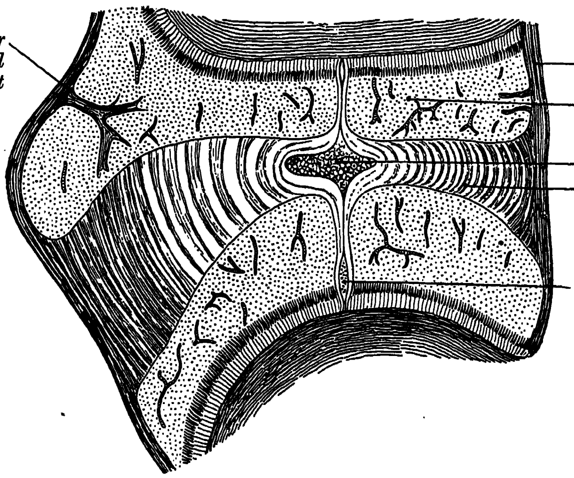
Special reference must be made to a structure which, although present in the *blastemal* period, only becomes recognisable as a separate entity subsequent to chondrification. This structure is named the **hypochordal bow.** It connects the vertebral ends of the two costal processes to each other across the ventral surface of the centrum (fig. 111), and, it should be observed, is only

found in connexion with the upper three or four cervical vertebræ. In the case of the atlas the hypochordal bow persists, and becomes ossified during the third year to form its anterior arch and the anterior ends of its lateral masses. In the cases of the succeeding vertebræ the hypochordal bow undergoes degeneration, and subsequently either disappears in its entirety or becomes incorporated in the anterior part of the centrum.

The notochord can still be identified traversing the centra of the cartilaginous column. Ultimately the portions within the centra atrophy and disappear, but the portions in the intervertebral discs are said to expand and persist throughout life as the central *nucleus pulposus* of each disc (p. 436).

Towards the end of the second month of intra-uterine life centres of *ossification* appear in the cartilaginous vertebræ, and the vertebral column enters on

FIG. 112.—A sagittal section through an intervertebral disc and the adjacent parts of two vertebræ of the embryo of a sheep. (Kölliker.)



its fourth and last stage, viz. that of ossification. The details of this process are described on p. 224.

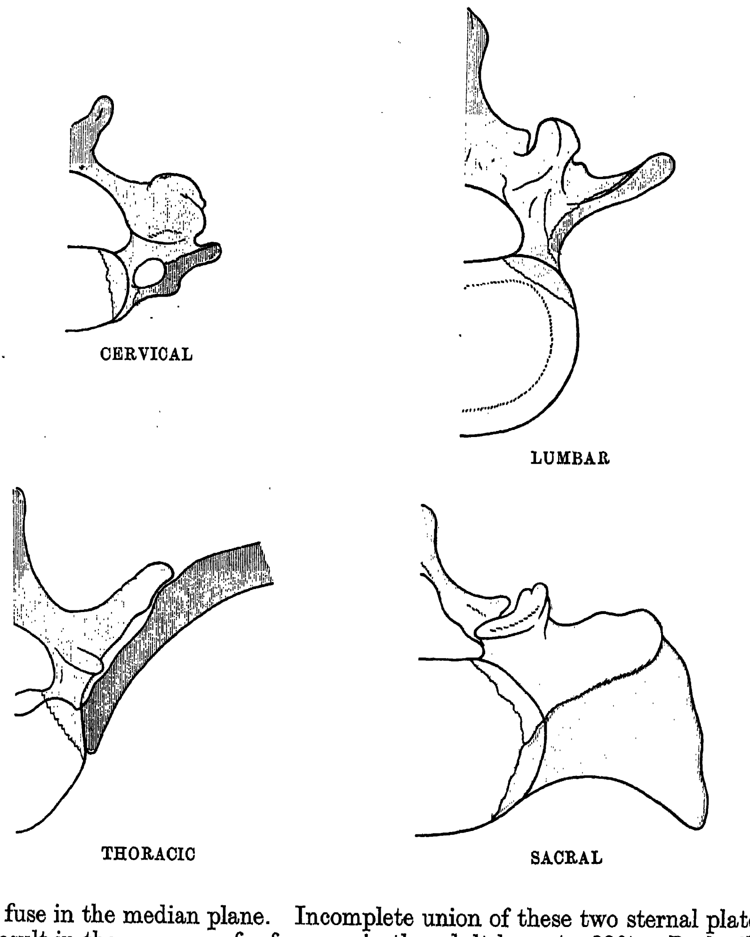
Applied Anatomy.—Occasionally the coalescence of the laminæ is not completed, and consequently a cleft is left in the arches of the vertebræ, through which a protrusion of the spinal membranes (dura mater and arachnoid), and generally of the spinal cord and pia mater, takes place, constituting the malformation known as *spina bifida*. This condition is most common in the lumbosacral region, but it may occur in the thoracic or cervical region, or the arches throughout the whole length of the canal may remain incomplete.

The ribs.—The ribs are formed from the costal processes of the primitive vertebral arches, the processes extending between the muscle-plates. In the *thoracic region* of the vertebral column the costal processes grow laterally to form a series of arches termed the *primitive costal arches*. The transverse process grows out behind the vertebral end of the costal process, and is at first connected to it by mesenchyme which is later differentiated to form the ligaments of the costotransverse joint; between the costal process and the tip of the transverse process the costotransverse joint is formed by absorption, while the proximal end of the costal process becomes separated from the neural arch by the development of the costocentral joint. In the *cervical vertebræ* (fig. 113) the transverse process forms the posterior boundary of the foramen transversarium, while the costal process, corresponding to the head and neck of the rib, remains in continuity with the body of the vertebra, and forms the anterior and lateral boundaries of this foramen. The distal portions of the primitive costal arches remain undeveloped; occasionally, however, the costal processes of the seventh cervical vertebra undergo greater development, and by the formation of costovertebral joints are separated off as cervical ribs. In the *lumbar vertebræ* the distal portions of the primitive costal arches fail; the proximal portions fuse

with the transverse processes to form the transverse process of descriptive anatomy. Occasionally a pair of movable ribs is developed in connexion with the first lumbar vertebra. In the *sacral vertebræ* costal processes are developed only in connexion with the upper three or four vertebræ; the processes of adjacent segments fuse with one another to form the anterior portions of the lateral masses of the sacrum. The *coccygeal vertebræ* are devoid of costal processes.

The **sternum**.—The ventral ends of the upper nine ribs become united to one another by a longitudinal bar termed the *sternal plate*, and the two sternal

Fig. 113.—Diagrams showing the portions of the adult vertebræ derived respectively from the centra (yellow), neural arches (pink), and costal processes (blue) of the embryonic vertebræ.



plates fuse in the median plane. Incomplete union of these two sternal plates may result in the presence of a foramen in the adult bone (p. 230). Both ribs and sternal plates consist at first of condensed mesenchyme, which later becomes chondrified. The eighth and ninth ribs lose their connexion with the sternum, and the portion so freed becomes the xiphoid process. This process of separation may be arrested too soon, and in this event the number of true ribs is increased to eight, or it may be carried too far and so cause a reduction in the number from seven to six. The ossification of the ribs and sternum is described on pp. 232 and 237.

The **skull**.—The bones of the cranium are developed in the mesenchyme which invests the cerebral vesicles, but, before the osseous stage is reached, the skull passes through, firstly, a blastemal or membranous stage, and, secondly, a cartilaginous stage. The chrondrocranium, which is formed in the second stage, is incomplete, and most of the cranial vault and portions of the base are not preformed in cartilage.

The membranous or blastemal skull.—At the end of the first month of intra-uterine life and the beginning of the second, the mesenchyme which surrounds the developing brain increases in thickness and forms localised masses which represent the earliest distinguishable elements of the skeleton of the head. These masses first become evident in the occipital region, where they form the *occipital plate,* which outlines the basilar part of the occipital bone. Two extensions grow laterally from each side of the plate, and their lateral extremities fuse with each other to complete a foramen around the hypoglossal nerve. At the same time the mesenchymal condensation extends forwards, dorsal to the pharynx, and reaches the rudiment of the hypophysis cerebri, thus outlining the clivus and dorsum sellæ of the sphenoid bone. Early in the second month it surrounds the duct of the hypophysis cerebri and extends between the right and left halves of the nasal cavity, where it forms the basis of the ethmoid bone and nasal septum.

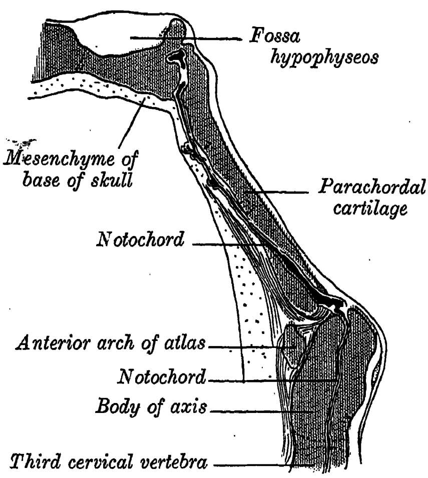


FIG. 114.—A sagittal section through the cephalic end of the notochord. (Keibel.)

The notochord traverses the occipital plate obliquely from its dorsal to its ventral surface and comes into intimate relation with the epithelium of the dorsal wall of the pharynx, with which it is for a time directly connected. It re-enters the base of the membranous skull and runs forward to terminate caudal to the hypophysis (fig. 114).

About the fifth week the two auditory vesicles (p. 130) become enclosed in mesenchymal capsules, each of which is soon differentiated into a dorsilateral part enveloping the semicircular ducts, and a ventrimedial part surrounding the cochlea; at the upper boundary between these two parts the facial nerve lies in a deep groove. The auditory capsules fuse with the lateral processes of the occipital plate, leaving a wide gap through which the internal jugular vein, and the glosso-pharyngeal, vagus and accessory nerves are transmitted.

At this stage the mesenchyme which surrounds the hypophyseal duct and forms the rudiment of the post-sphenoid part of the body of the sphenoid bone sends out a wing-like process on each side—the future greater wing. More anteriorly, from the central mesenchyme which is to form the interorbitonasal septum, processes extend laterally and indicate the sites of the lesser wings of the sphenoid bone, while condensations occur on each side of the nasal cavity and blend above with the mesenchymal septum.

The first indications of the vault of the skull are seen about the thirtieth day, and consist of plates of mesenchyme which appear at the sides of the head and gradually extend into the upper wall where they blend with one another; they also blend with the parts at the base of the cranium.

In the shark and dogfish this mesenchymal cranium undergoes complete chondrification and forms the cartilaginous skull or chondocranium of these animals. Chondrification takes place primarily in two regions: (*a*) the anterior or *prechordal* part is developed in front of the notochord and shows no regular division into primitive segments; (*b*) the posterior or *chordal* part of the base of the skull is developed from the mesenchyme which surrounds the notochord, and exhibits traces of four primitive segments separated from one another by the roots of the hypoglossal nerve.

In mammals the process of chondrification is limited to the base of the skull, including a region dorsal to the foramen magnum. Chondrification takes place primarily in three regions: (*a*) posterior, in relation to the notochord; (*b*) intermediate, in relation to the hypophysis; and (*c*) anterior, between the orbits and the nasal cavity. These parts may be named *chordal, hypophyseal,* and *interorbitonasal*; perhaps the last is identical with the trabeculæ cranii of the majority of vertebrates lower than mammals. It is uncertain what the hypophyseal part represents; when ossified it forms the post-sphenoid.

* In man chondrification of the skull (figs. 115, 116, 117) begins in the second month of intra-uterine life, and the first cartilaginous nuclei appear in the occipital plate, one on each side of the notochord. About the thirty-sixth day these two nuclei fuse anteriorly on the dorsal surface of the notochord, and later they fuse posteriorly on its ventral surface. Thus the notochord lies dorsal to the caudal part of the cartilaginous occipital plate, then

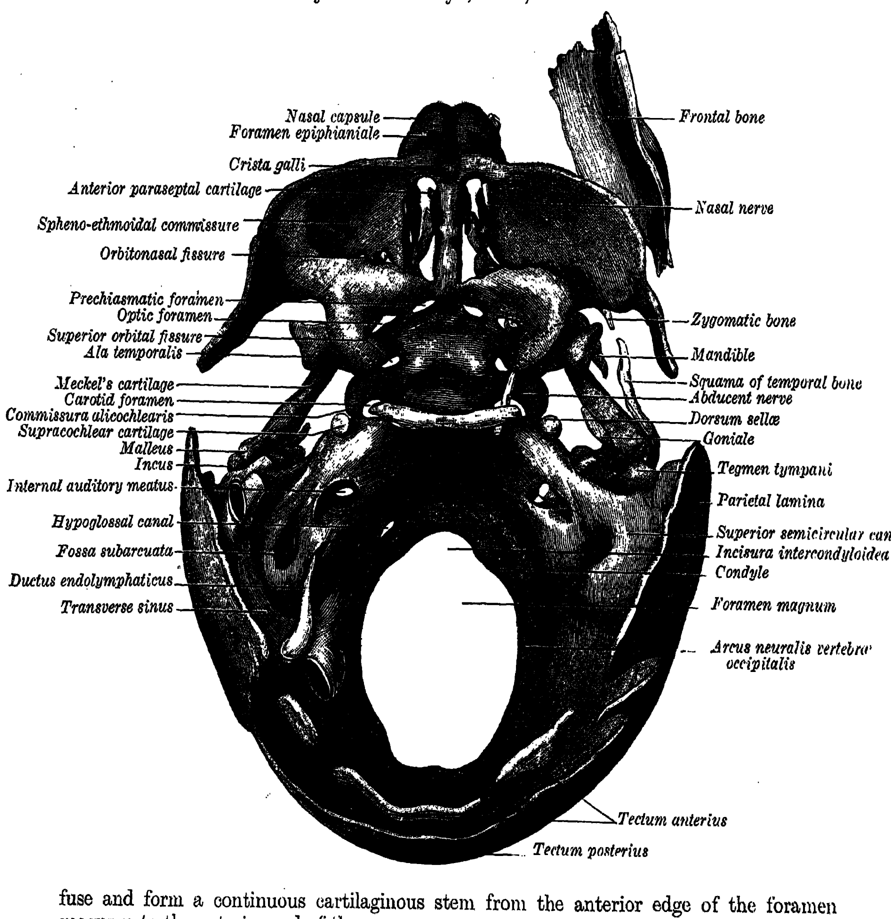
* The following description is mainly based on the researches of Professor E. Fawcett. The reader is referred for further details to the *Journal of Anatomy and Physiology,* volumes xlv., li., and lii., and to the *Proceedings of the Anatomical Society of Great Britain and Ireland,* 1916.

traverses the plate and lies ventral to it, and finally passes forwards in front of it and ends in the dorsal surface of the post-sphenoid cartilage (fig. 114).

The posterior part of the sphenoid cartilage chondrifies from two centres, one on each side of the developing hypophysis cerebri; these unite first behind the duct of the hypophysis and then in front of it, and in this way the craniopharnygeal canal, which transmits the hypophyseal diverticulum, is formed; this canal is usually obliterated at the third month, but may remain open.

The mesenchyme in front of the hypophysis cerebri undergoes independent chondrification; it speedily joins with the posterior end of the chondrifying interorbitonasal septum, and from these are subsequently developed the presphenoid part of the sphenoid bone and the bony (ethmoid) part of the nasal septum. All the above-mentioned parts ultimately

Fig. 115.—The chondrocranium of a human embryo of a crown-rump length of 27 mm. Superior aspect. (From a model prepared by Prof. Edward Fawcett and Gwladys Ruth Llewelyn, B.Sc.)



fuse and form a continuous cartilaginous stem from the anterior edge of the foramen magnum to the anterior end of the nose.

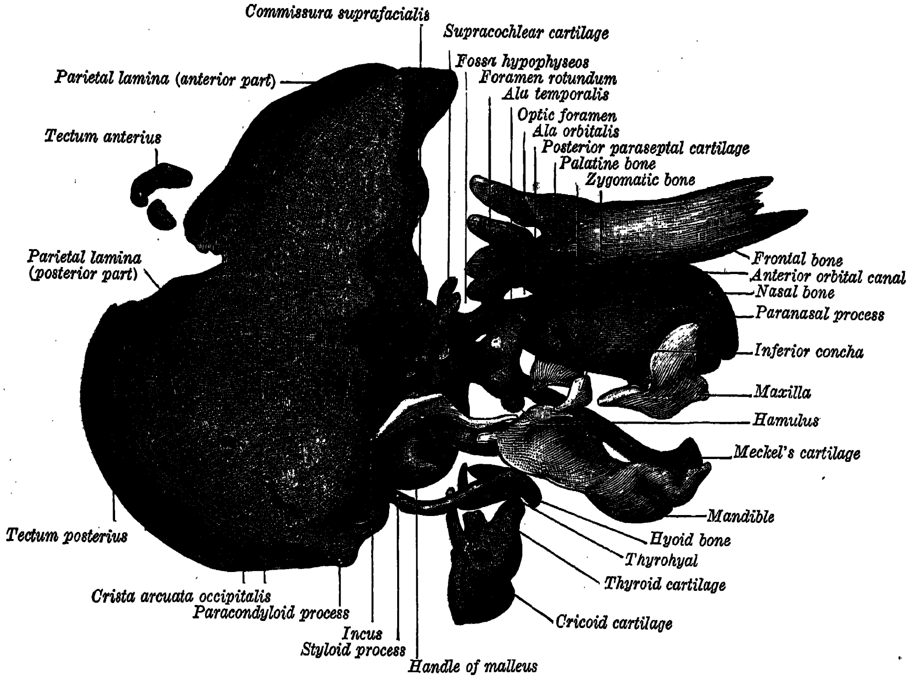
The auditory capsule next undergoes chondrification, the portion surrounding the semicircular ducts chondrifying before that enveloping the cochlea. A plate of cartilage is connected to the top of each auditory capsule by means of a cartilaginous commissure. At the third month this plate forms a considerable part of the side-wall of the cranium, and is separated by only a small interval from the hinder end of the lesser wing of the sphenoid bone. The distance between the two rapidly increases owing to the disappearance of the cartilage.

It is highly probable that the roof of the cranium in its typical human condition is formed by three tecta, which may be called the *tectum posterius*, *tectum intermedium*, and *tectum anterius*. The tectum posterius is the deepest, and when ossified forms the supra-occipital segment of the occipital bone. The tectum intermedium is very narrow and lies immediately in front of the tectum posterius; it soon disappears, and may not even form. The tectum anterius, which stretches between the two parietal plates, is a compound structure consisting of two lateral pieces, one on each side, and a median unpaired segment. Like the tectum intermedium, it soon disappears.

The greater wings of the sphenoid bone have separate cartilaginous nuclei; these fuse with the post-sphenoid cartilage and with two nuclei which connect the post-sphenoid cartilage and the corresponding greater wing with the anterior end of the cochlear capsule, lateral to the carotid artery. These nuclei form, on each side, the alar process, which later ossifies as the lingula. The cartilaginous greater wing is smaller than the lesser wing and only gives rise to the root of the pterygoid process and to that part of the bone which surrounds the maxillary division of the trigeminal nerve.

Between the greater wing and the auditory capsule a wide space lodges the trigeminal (semilunar) ganglion, and transmits the mandibular division of the trigeminal nerve and the

FIG. 116.—The chondrocranium shown in fig. 115. Lateral aspect.



middle meningeal artery. The backward growth of the alar process cuts off this space from the carotid canal, and at a later date the mandibular nerve and middle meningeal artery are surrounded by membrane bone. The space between the greater and lesser wings forms the superior orbital fissure.

A cartilaginous centre appears in the lesser wing, lateral to the optic nerve; it grows medially in front of the nerve and also behind it and fuses with the hinder part of the interorbitonasal septum and so forms the optic foramen. Ossification of the lesser wing begins just lateral to the optic foramen, but does not extend very far laterally; a considerable part of the cartilage disappears, and, owing to this, the size of the bony lesser wing is less than that of the greater wing.

The *nasal capsule* is situated in front of the lesser wings, and is well developed by the third month; it consists of a central part or septum, and two lateral parts.

The septum lies partly under the brain (subcerebral) and partly in front of the brain (precerebral); its lower margin is almost horizontal and is, for a time, free; its anterior border intervenes between the nares.

The lateral parts of the capsule are primarily suspended from the precerebral part of the septum; posteriorly, they are separated from the subcerebral part by the orbitonasal fissure, but later they become connected with it when the cartilaginous cribriform plate of the ethmoid bone develops. The lower edge of the lateral wall of the capsule is incurved to form the inferior nasal concha, which ossifies at the fifth month and becomes detached from the capsule. The posterior part of the lateral part of the capsule becomes ossified to form the ethmoidal labyrinth, and the middle and superior conchæ appear as ridges on its medial surface (fig. 117).

The floor of the cartilaginous nasal capsule is far from complete (fig. 117). The deficiency in the floor of the cartilaginous nares is continued backwards as the fissura rostroventralis. On each side of the free lower margin of the nasal septum there are two para-

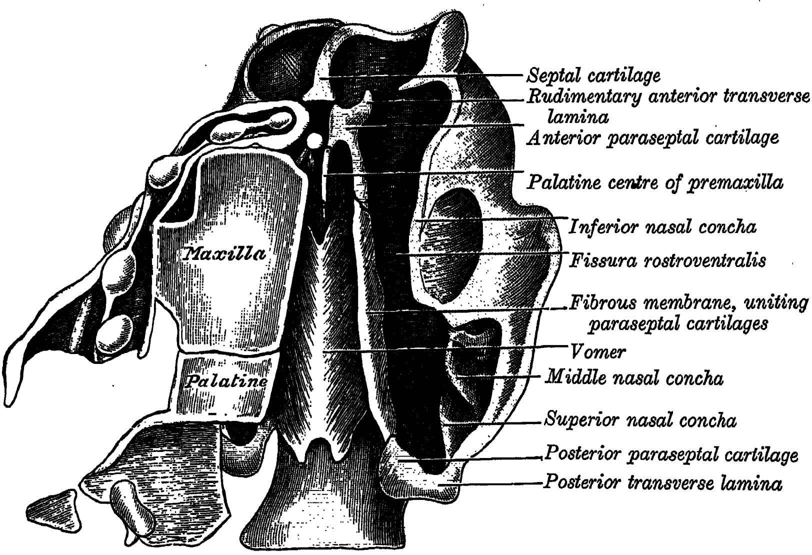
septal cartilages, connected to each other by a fibrous membrane, and represented in lower mammals by a single cartilaginous bar. The anterior paraseptal cartilage is closely related to the vomero-nasal organ; the posterior paraseptal cartilage is connected by a narrow transverse lamina to the postero-inferior corner of the lateral part of the capsule (fig. 117).

Part of the cartilaginous nasal capsule, as already stated, is ossified to form the ethmoid bone and the inferior nasal conchæ, but part remains cartilaginous as the septal and alar cartilages of the nose, and part is replaced by membrane bones.

The ventral surface of the chondrocranium is indirectly connected with the cartilages of the visceral arches, the fate of which is described below.

It will be observed from the accompanying figures that the stage of ossification commences before the chondrocranium has yet reached the height

FIG. 117.—The nasal capsule of a human embryo 65 mm. long. Ventral aspect. On the left side the floor of the capsule has been removed. (From a model by Professor Edward Fawcett.)



of its development. As the process of ossification extends the chondrocranium, after reaching its maximum extent, becomes rapidly reduced, but portions of it still persist at birth, and some are found in the adult skull. At birth the cartilage of the chondrocranium is present: (1) in the cartilages of the alæ and septum of the nose; (2) in the sphenoid bone (p. 294); (3) in the spheno-occipital (p. 426) and the petro-occipital joints (p. 426); and (4) in the foramen lacerum.

The bones of the vault of the skull are ossified in membrane, and are termed *dermal* or *covering bones*. They comprise the frontal and parietal bones, the upper part of the squama occipitalis (interparietal bone), and the squamous and tympanic parts of the temporal bones. Some of the dermal bones remain distinct throughout life (e.g. parietal and frontal), while others join with the bones of the chondrocranium (e.g. interparietal and squamous parts of temporals). The ossification of the bones of the skull is given with the description of the individual bones.

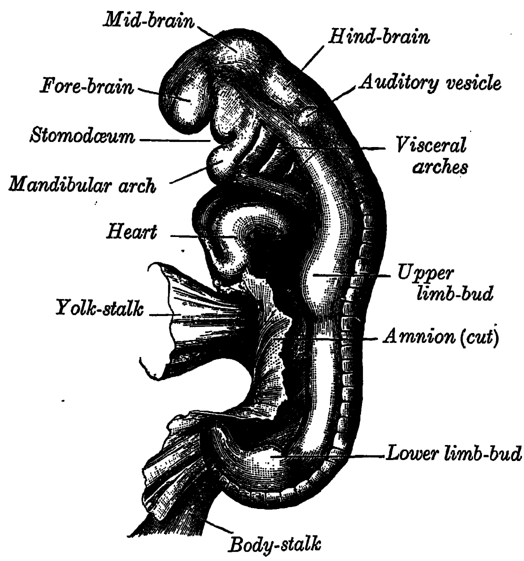
The development of the appendicular skeleton is dealt with on p. 101.

THE BRANCHIAL APPARATUS

After the formation of the head-fold the stomodæum, or primitive mouth, is bounded on its headward side by the forward projection of the fore-brain and on its caudal side by the pericardium. The lower part of the face and the

whole of the neck, which subsequently intervene between the mouth and the pericardium, owe their formation to the development of a series of six **visceral arches** which appear on the lateral aspect of the head in the region of the hind-brain. The first of these arches corresponds to the lower jaw of the fish, the second to the operculum or gill cover, and the remaining four to the branchial or gill arches. The mesenchyme on the lateral wall of the headward part of the fore-gut (lateral plate mesoderm) (p. 61) at first forms a thin sheet intervening between the ectoderm and the entoderm but, as growth proceeds, it proliferates and gives rise to a series of somewhat cylindrical processes which constitute the arches. At first the arches form rounded ridge-like projections in the overlying ectoderm and corresponding projections in the entodermal floor of the pharynx. These ridges are separated from one another by a series of furrows, where the surface ectoderm and the pharyngeal entoderm come into direct contact with one another. The ectodermal furrows are termed the **branchial** or **visceral clefts** and the entodermal furrows the **pharyngeal pouches.** At this stage the pharynx, which is wide at its cephalic end but rapidly narrows as it is traced caudally, is very shallow dorsi-ventrally. It possesses a wide roof and a wide floor, which meet on each side, so that there is no true lateral wall (fig. 119).

FIG. 118.—A human embryo, 4·2 mm. long. Left lateral aspect. (His.)



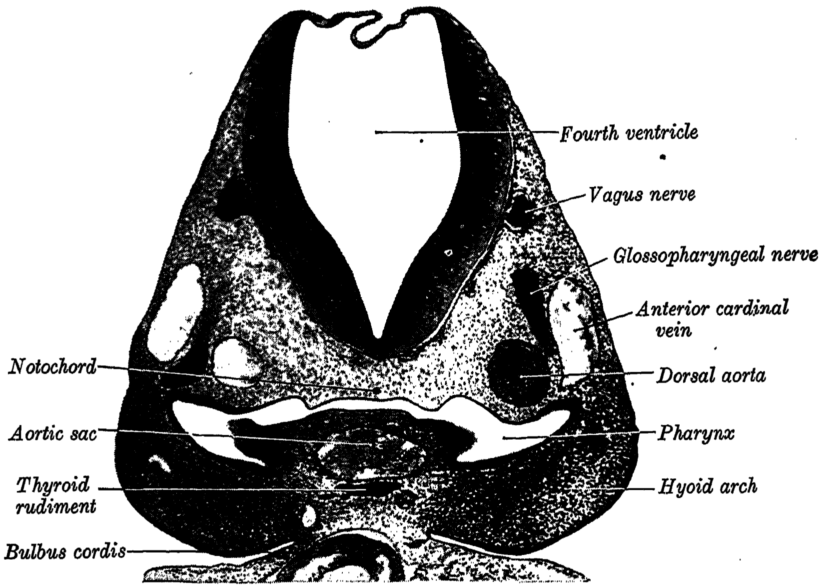
The early appearance of the arches and their intimate relationship to the mouth and to the heart and pericardium, not only in man but in the embryos of all the vertebrata, are explained by their functional significance in the lower vertebrates. They provide for water-breathing animals a convenient and efficient respiratory apparatus. From the arterial, headward end of the heart there emerge two ventral aortæ which pass headwards on the ventral aspect of the pharynx and send branches dorsally, one entering the substance of each arch. In the substance of the arches these vessels break down into a thin-walled capillary plexus from which corresponding vessels emerge and run dorsally to join the dorsal aortæ—two large vessels situated on the dorsal aspect of the pharynx. The branchial clefts in these animals break down and a series of gill slits develop which communicate between the exterior and the inside of the pharynx. Periodically the oxygen-bearing water is taken into the pharynx through the mouth and expelled through the gill slits. In its passage it bathes the entodermal surfaces of the branchial arches, which are specially adapted to expose to it a large area filled with capillaries. The blood gives up its carbon dioxide and absorbs fresh oxygen in its place, and this oxygenated blood is carried into the dorsal aortæ to be distributed all over the body. The periodic intake of water for this purpose is the equivalent of inspiration in an air-breathing vertebrate, and the process provides a respiratory mechanism in which water and not air is the oxygen carrier.

The *first* or *mandibular arch* grows ventrally and medially in the floor of the pharynx until it meets the corresponding arch of the opposite side in the median plane. It comes to lie, therefore, between the primitive mouth and the pericardium (fig. 118). The *second* or *hyoid arch* grows ventrally on its caudal side, and separated from it on the outside by the first cleft. It, too, ultimately reaches the median plane and fuses with its fellow. The

succeeding *third* and *fourth arches* never attain any great degree of prominence, and are for the most part sunk in a depression produced by the caudal overlapping of the hyoid arch. The *fifth* and *sixth arches* cannot be recognised on the outside of the neck and their presence can only be demonstrated by the arrangement of the mesenchyme and the projections in the pharyngeal wall.

It should be observed that each arch consists of an ectodermal covering, a mesodermal core, and an entodermal covering (fig. 119). The mesodermal core gives rise to a *skeletal element*, which subsequently chondrifies in whole or in part and extends dorsally until it comes into contact with the membranous capsule of the hind-brain. Most of the remainder of the mesodermal core later gives rise to striated *muscle*, which may migrate and lose all attachment to the

Fig. 119.—Coronal section through the head of a mole embryo, 4·5 mm. long. The section passes through the hind-brain, the pharynx, the hyoid and a part of the third visceral arch.



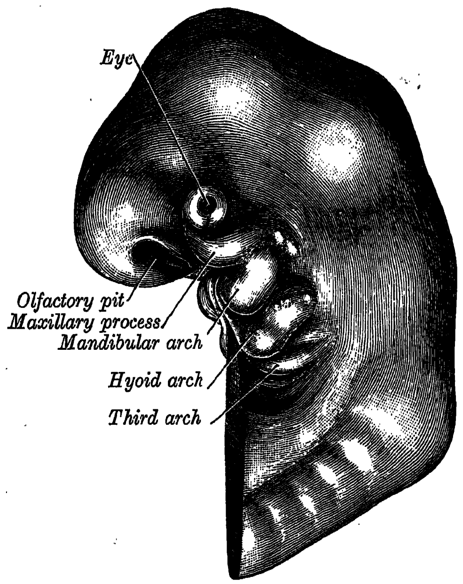
primitive skeletal element of the arch. The history of these muscle masses can, however, easily be traced by reference to their nerve-supply. The dorsal end of each arch, as has already been pointed out, lies close to the ventrilateral aspect of the hind-brain (fig. 119) and the motor *nerves* which arise from this part of the brain pass directly into the arches. The innervation of the muscle masses once established will persist, no matter how far the muscle may migrate from the site of its development. Thus, the mandibular division of the trigeminal nerve supplies the mandibular arch ; the facial nerve, the hyoid arch ; the glossopharyngeal, the third arch ; the vagus and accessory, the remaining arches. It is probable that the recurrent laryngeal nerve is distributed to the sixth arch and the superior laryngeal to the fourth, but the individual nerve of the fifth arch—which is always difficult to identify and leaves few traces of its existence—is uncertain.

The development of the branchial apparatus plays an important part in the formation of the face and neck, the mouth, the pharynx and the larynx, but before a detailed survey is made of the history of the arches it is convenient at this stage to describe the steps which lead to the formation of the face and the demarcation of the nasal cavity.

Development of the face, nose and palate.—While the mandibular arch is invading the floor of the pharynx, the mesenchyme which intervenes between the floor of the fore-brain and the epithelial roof of the mouth becomes thicker

and deeper and, together with its covering ectoderm, constitutes the *frontonasal process*. During the fifth week a thickened patch of ectoderm appears on the ventrilateral surface of the frontonasal process on each side. These specialised patches, which are widely separated from each other, are termed the *olfactory placodes*, and they soon become depressed to form the *olfactory pits*. The frontonasal process can now be subdivided into a *median nasal process*, which occupies the wide field intervening between the pits, and two *lateral nasal processes*, which lie on either side of it.

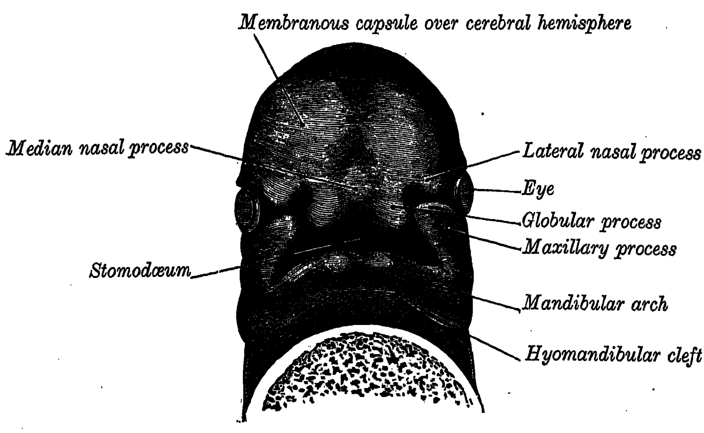
Fig. 120.—The head-end of a human embryo, about the fifth week. Lateral aspect. (From a model by Peter.)



While these changes are in progress a somewhat triangular process grows ventrally from the cephalic side of the dorsal end of the mandibular arch. It is termed the *maxillary process* and, like the frontonasal process, it consists of a core of mesenchyme covered with ectoderm. The maxillary process grows ventrally to fuse with the lateral nasal process, from which it is separated at first by a groove, termed the *naso-optic furrow*. While it is enlarging, the median nasal process gives origin to two rounded swellings, termed the *globular processes*, which project beyond the lateral nasal processes and grow dorsally and laterally below the olfactory pits.

The opposed margins of the lateral nasal and maxillary processes fuse with each other to establish continuity between the side of the nose and the adjoining

Fig. 121.—The head of a human embryo 8 mm. long. Ventral aspect. (From a model by His.)



part of the cheek (fig. 125). The ectoderm along the line of fusion does not disappear, but gives rise to a solid, cellular rod, which sinks beneath the surface. Its caudal, free end secondarily establishes a connexion with the caudal part of the lateral wall of the nasal cavity. Later, this rod becomes canaliculised to form the *nasolacrimal duct*. The blunted apex of the triangular maxillary process projects beyond the lateral nasal process and carries that process on its cephalic surface to meet and fuse with the globular process below

the olfactory pit (figs. 122 and 123). In this way a new upper boundary is formed for the oral fissure by the globular and maxillary processes. It is really the upper lip, although it has not yet been freed from the deeper tissues which form the maxillary alveolus (figs. 126 and 128). At the same time the olfactory pit is converted into a shallow nasal cavity, and now possesses a floor formed by the lateral nasal and maxillary processes. At this stage the nares are completely defined, but they are still widely separated from each other by an area which later becomes relatively narrower, owing to the fusion of the mesenchymal cores of the globular processes. The mesenchyme of the maxillary processes invades the median area and makes a substantial contribution to the formation of the *philtrum* of the upper lip (fig. 125). This invasion of the median area explains the innervation of the philtrum by the maxillary nerve.

FIG. 122.—The head-end of a human embryo in the sixth week. Ventral aspect. (From a model by K. Peter.)

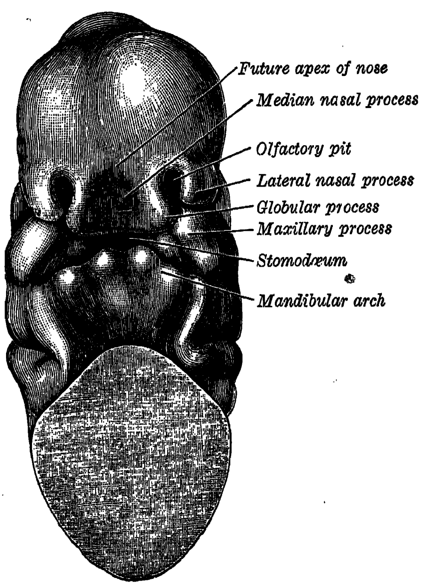
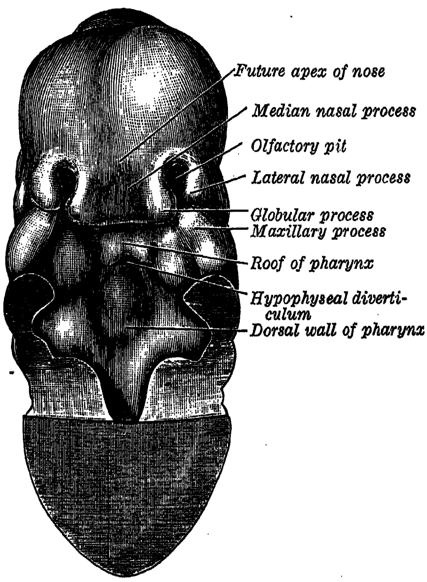


FIG. 123.—The same embryo as is shown in fig. 122, with the front wall of the pharynx removed.



The nasal cavity deepens, and for a time it is only separated from the cavity of the mouth on each side by the *bucconasal membrane*, which consists of the epithelial lining of the pit and the epithelial lining of the roof of the mouth (fig. 126). This membrane ruptures about the fifth week and *primitive posterior nasal apertures* open on the fore part of the roof of the mouth. The area between these openings and the line along which the teeth subsequently develop, constitutes the *primitive palate* (fig. 126), since it intervenes between the cavities of the mouth and nose.

As the head grows in size the mesenchyme which intervenes between the floor of the fore-brain and the mouth increases greatly in amount and the nasal fossæ deepen (i.e. extend towards the fore-brain). At the same time they extend backwards from the primitive posterior nasal apertures as two narrow but deep grooves in the roof of the mouth, separated by a broad partition which increases in depth as the fossæ deepen. This partition is the *nasal septum*, and its broad caudal surface lies free in the roof of the mouth and is at first in contact with the dorsum of the developing tongue (fig. 127). The nasal cavity is thus subdivided into right and left parts, which communicate freely with the cavity of the mouth except ventrally, where the floor is formed by the primitive palate.

In the sixth week the inner surface of the maxillary process gives rise to a *palatine process*, which projects caudally from it and lies in contact with the side of the tongue (fig. 127). The two palatine processes are separated at first by the whole breadth of the tongue, and at this stage the cephalic margin of the oral

fissure extends ventrally beyond the caudal margin. Further growth of the mandibular region in a ventral direction carries the tongue with it *caudal* to the ventral ends of the palatine process, which thereafter grow towards each other and coalesce in the interval between the tongue and the free margin of the nasal septum (fig. 129). As the palatine processes fuse with each other, they fuse also with the caudal border of the nasal septum in its ventral three-fourths, leaving

FIG. 124.—The face of a human embryo of about eight weeks, in which the nose and mouth are formed. (From a model by His.)

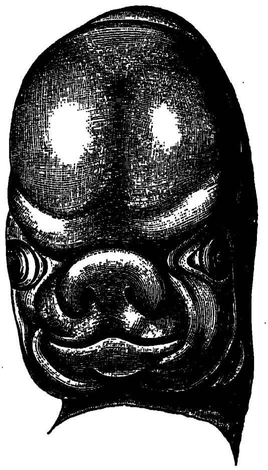
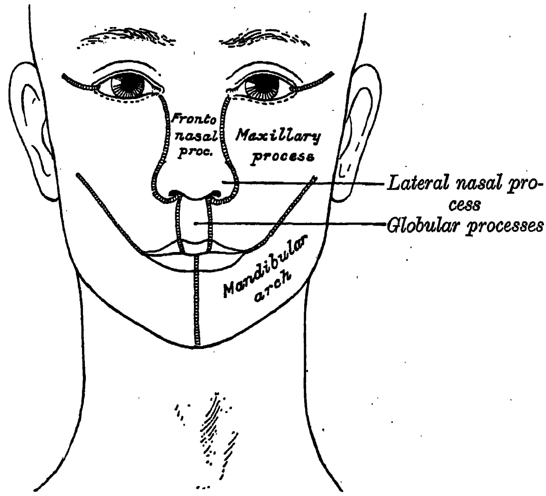
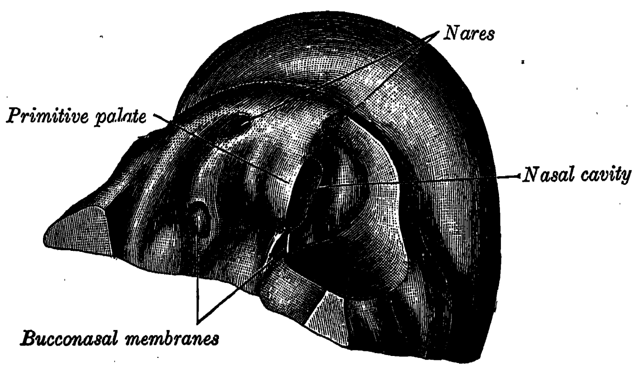


FIG. 125.—A diagram showing the parts of the adult face which are related to the frontonasal and maxillary processes and the mandibular arch.



its dorsal fourth free to form the posterior margin of the septum in the adult. In this way the *definitive posterior nasal apertures* are established, opening above the palate into the nasal pharynx. Later, the palatine processes are continued backwards on the side wall of the pharynx and meet and fuse with each other to form the soft palate. At their ventral ends the palatine processes encroach on the primitive palate, which retains its position and constitutes the premaxillary portion in the adult.

FIG. 126.—The primitive palate of a human embryo in the seventh week. (From a model by K. Peter.)

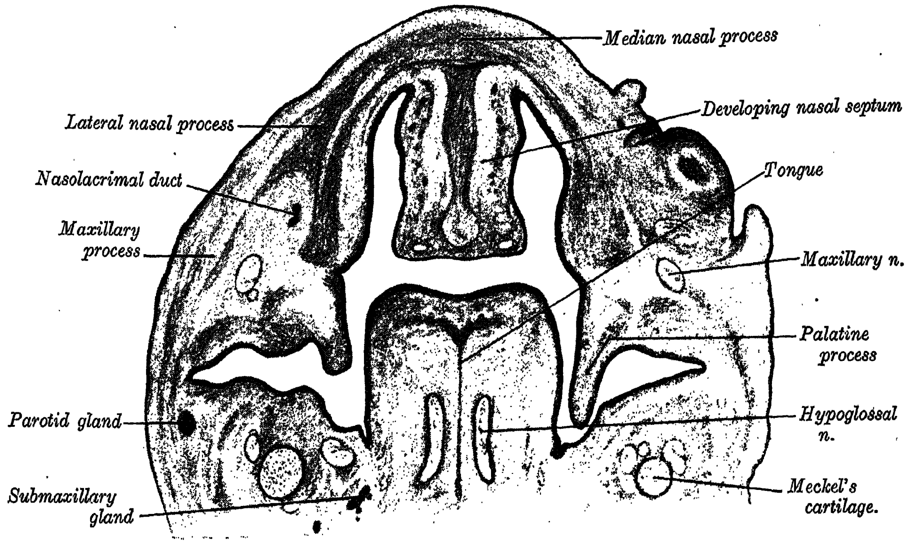


On the left side the lateral wall of the nasal cavity has been removed.

On each side of the nasal septum, at its caudal and ventral part, the ectoderm is invaginated to form a diverticulum which extends dorsally and headwards into the nasal septum. These diverticula form the *vomeronasal organs*, which open below, close to the junctions of the premaxillæ and maxillæ, but they are always rudimentary in man.

Congenital malformations involving arrest of development during the formation of the face and palate are not uncommon. In the simplest form, the maxillary process on one side fails to fuse completely with the globular process and a fissure is present between the philtrum and the lateral part of the upper lip. The condition is known as *hare-lip*. A similar type of malformation, but of comparatively rare occurrence, results from the failure of the maxillary process to fuse with the frontonasal process. In this case the nasolacrimal duct

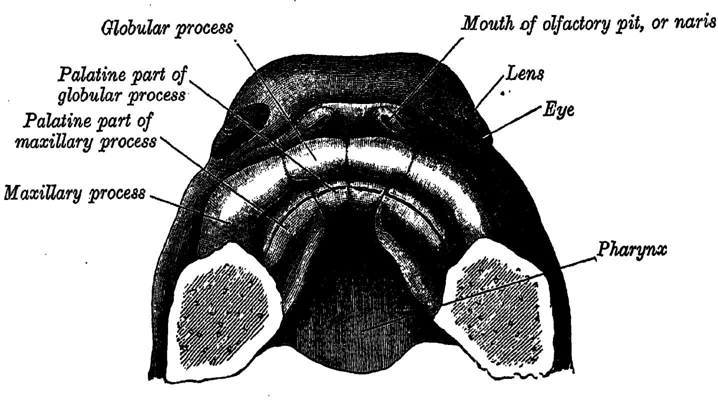
FIG. 127.—Oblique coronal section through the head of a human embryo 23 mm. long. The nasal fossæ communicate freely with the cavity of the mouth.



forms an open furrow along the side of the nose, and the condition is usually associated with the presence of hare-lip on the same side.

The palatine processes may fail to fuse with each other and with the nasal septum, giving rise to the condition of *cleft palate*. In its grossest form no fusion occurs in the roof of the mouth. The edges of the palatine process are separated by a wide median fissure in which the free lower border of the nasal septum can be seen. Anteriorly the premaxillary

FIG. 128.—The roof of the mouth of a human embryo about two and a half months old, showing the mode of formation of the palate. (From a model by His.)

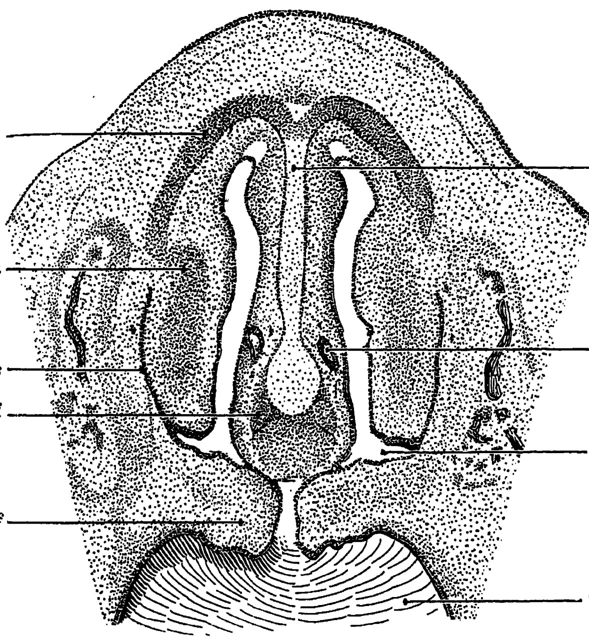


portion of the palate is separated from the palatine processes by a fissure on each side, and these fissures are continuous in front with the clefts in a double hare-lip. In such cases the median nasal process remains separate, but it is, of course, continuous above and behind with the nasal septum. The floor of the nasal fossa is deficient throughout its whole extent and the posterior nasal apertures have never been defined. All varieties of milder degrees of cleft palate have been recorded. In the commonest type the condition is unilateral, i.e. one palatine process has fused with the primitive palate and with the nasal septum, but the other

has failed to do so and the extent of the cleft is variable. The mildest degree results in a bifid uvula only, or in a cleft which affects the soft palate only.

Such arrests of development are indicative of nutritional disturbances in the embryo during the second month of development, and the grosser varieties are usually associated with malformations affecting other parts of the body.

FIG. 129.—A coronal section through the nasal cavity of a human embryo 28 mm. long. (Kollmann.)



The subsequent history of the visceral arches.—The visceral arches contribute extensively to the formation of the face, the neck, the mouth, the pharynx and the larynx ; the visceral clefts, with the exception of the first, which forms the external auditory meatus, disappear entirely ; the pharyngeal pouches give origin to the tympanic cavity and the pharyngo-tympanic (auditory) tube, the tonsillar pits, the thymus and the parathyroids.

Ectodermal derivatives.—The ectoderm over the mandibular arch is responsible for the formation of that part of the skin of the face which covers the mandible (fig. 125) and, in addition, it takes part in the formation of the auricle (p. 132). The ectoderm on the cephalic aspect of the arch thickens along a curved line which is later converted into the labiodental sulcus. The epithelial proliferation invades the underlying mesenchyme and subsequently breaks down, so as to separate the lower lip from the developing gum. Before it does so, however, it gives rise on its inner surface to an epithelial lamina (fig. 1136) from which the enamel of the teeth is derived at a later stage (p. 1279).

The first cleft becomes obliterated in its ventral portion, but its dorsal end, surrounded by tubercles which arise from the mandibular and hyoid arches to form the auricle, deepens and forms the epithelial lining of the external auditory meatus.

At the end of the fifth week the third and fourth arches lie at the bottom of a small depression, which is termed the *precervical sinus*. On the cephalic side the sinus is bounded by the hyoid arch ; dorsally, by a ridge produced by downgrowths from the occipital myotomes and by premuscle tissue which subsequently forms the sternomastoid ; and caudally, by a smaller ridge termed the epipericardial ridge (Frazer) which separates the sinus from the pericardium and curves headwards, medial to the ventral ends of the arches to reach the mandibular arch. The muscle cells which migrate from the occipital myotomes to reach the tongue follow the epipericardial ridge and carry the hypoglossal nerve with them. The fourth arch becomes buried by the growth of the dorsal border

of the sinus, which, together with the epipericardial ridge and the reduced second and third arches, eventually constitutes the whole of the side of the neck.

At the dorsal ends of the first, second and third clefts, thickened patches of ectoderm, termed *epibranchial placodes*, are intimately related, and may possibly make contributions, to the ganglia of the seventh, ninth and tenth cranial nerves. As growth proceeds they retain their relationship to the ganglia and therefore become more and more deeply placed, although for a time they remain connected to the surface by epithelial strands.

The above outline of the development of the neck follows the work of Frazer,* but it should be mentioned that it differs in several respects from the description current in most textbooks. According to the latter, the hyoid arch meets its fellow in the median plane and, caudally, grows over and buries the whole of the precervical sinus, fusing eventually with the ectoderm over the headward aspect of the pericardium.

The buried epithelium of the precervical sinus may give rise to a *branchial cyst*, or, if its connexion with the surface is retained, to a *branchial fistula*. In the latter case the opening of the fistula is placed low down in the neck, close to the anterior border of the sternomastoid muscle.

Mesodermal derivatives.—Each arch is traversed by an artery, which connects the ventral to the dorsal aorta and is termed an *aortic arch*. Phylogenetically each visceral arch possesses two nerves, one running along its cephalic and the other along its caudal border. In the human embryo this double innervation can only be determined in the first arch. Each arch contains a *skeletal element*, typically a bar of cartilage connected to the chondrocranium at its dorsal end and meeting its fellow of the opposite side at its ventral end. The cartilage develops *in situ* from the mesoderm of the arch, which also gives origin to a mass of *muscle*.

The first and second *aortic arches* of each side disappear, but the third aortic arch persists as the lower, or proximal, portion of the internal carotid artery and the distal part of the common carotid (fig. 130). The fourth aortic arch of the right side forms the proximal part of the right subclavian artery, but on the left side it becomes the part of the arch of the aorta which lies between the origins of the left common carotid artery and the left subclavian. The fifth aortic arch disappears entirely, but the sixth on each side gives off a branch to the developing lung-bud. When the truncus arteriosus becomes divided into the pulmonary trunk and the ascending aorta the sixth arches remain in connexion with the former. On the right side the dorsal portion of the sixth aortic arch disappears, but on the left side it forms the *ductus arteriosus*, which functions during intra-uterine life and becomes converted into the fibrous *ligamentum arteriosum* after birth.

The *nerves* of the arches are derived from the hind-brain and at once enter the dorsal ends of their arches. Typically, they are mixed nerves; their motor branches supply the muscle of the corresponding arch and their sensory branches are distributed to the skin and mucous membrane derived from it. In fishes the nerves and their ganglia lie at the dorsal ends of the clefts, and each sends a pretrematic branch into the arch on the cephalic side of its cleft and a post-trematic branch into the arch on its caudal side. In mammals, although both may be distinguished in the first arch, only one nerve can be identified with certainty in the second, third, fourth and sixth arches, while the nerve of the fifth arch is unknown and may have disappeared.

The mandibular division of the trigeminal nerve is the post-trematic nerve of the first arch, and the chorda tympani is its pretrematic nerve.† The facial supplies the second arch, the glossopharyngeal the third, the superior laryngeal nerve the fourth, and the recurrent laryngeal nerve the sixth. In lower animals the nerve to the fifth arch is a branch of the vagus.

The difference in the behaviour of the recurrent laryngeal nerves on the two sides of the body in the adult can be understood on reference to the history of the aortic arches. The nerve enters the arch caudal to the sixth aortic arch. It retains this position on the left side of the body, and in the adult is found on

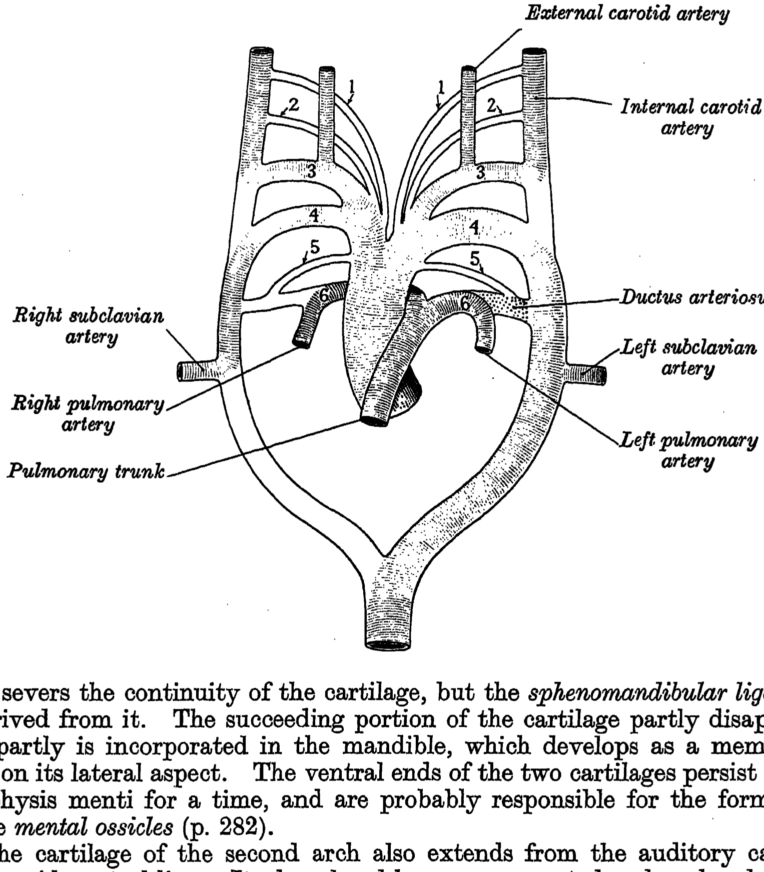
* J. Ernest Frazer, *Journal of Anatomy*, Oct. 1926.

† Professor Frazer does not regard the chorda tympani as a pretrematic nerve, for reasons explained in his *Manual of Embryology*, p. 242.

the left side of (i.e. caudal to) the ligamentum arteriosum. On the right side, however, owing to the disappearance of the dorsal part of the sixth aortic arch and of the whole of the fifth aortic arch, the nerve is found on the caudal aspect of the subclavian artery, i.e. the fourth aortic arch.

The *skeletal element* of the first arch is termed *Meckel's cartilage*. It extends from the basal aspect of the developing auditory capsule into the mandibular arch, and, ventrally, it turns upwards in contact with its fellow of the opposite side (fig. 116). The dorsal end of the cartilage becomes separated and forms the *incus* and the *malleus*, including its anterior process. The completion of the

FIG. 130.—A scheme of the aortic arches and their transformations. (After Congdon.)



skull severs the continuity of the cartilage, but the *sphenomandibular ligament* is derived from it. The succeeding portion of the cartilage partly disappears and partly is incorporated in the mandible, which develops as a membrane bone on its lateral aspect. The ventral ends of the two cartilages persist in the symphysis menti for a time, and are probably responsible for the formation of the *mental ossicles* (p. 282).

The cartilage of the second arch also extends from the auditory capsule to the mid-ventral line. Its dorsal end becomes separated and enclosed in the tympanic cavity, forming the *stapes*. Thereafter the cartilage is represented in the adult by the *styloid process*, the *stylohyoid ligament*, the *lesser cornu* and the *upper part of the body of the hyoid bone* (fig 131).

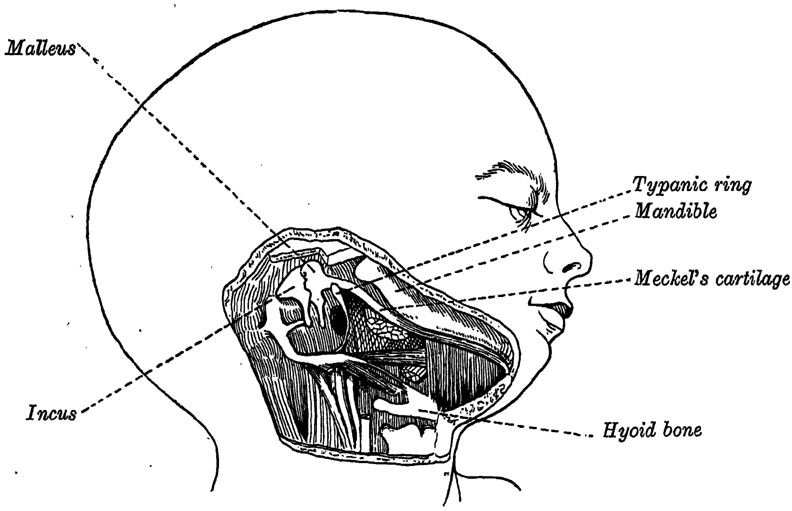
The cartilage of the third arch loses its connexion with the cerebral capsule, but its ventral portion persists as the *greater cornu of the hyoid bone* and the *lower part of its body*. According to Frazer, the body of the hyoid bone chondrifies in the base of the hypobranchial eminence and belongs to the third arch only, its connexion with the skeletal element of the second arch being acquired secondarily.

The cartilages of the fourth, fifth and sixth arches all lose their connexion with the cerebral capsule, but their ventral portions persist and take part in the formation of the cartilages of the larynx. The *thyroid cartilage* is formed from the fourth and, probably, the fifth; the *epiglottis* develops in the fourth arch, but it is very doubtful whether the skeletal element of this arch contributes to its formation. The *arytenoids* are derived from the skeletal elements of the sixth arches. The origin of the *cricoid* is uncertain. Most authorities

regard it as a modified tracheal ring which has become included in the larynx, but Fawcett * believes that it is derived from the skeletal element of the fifth arch and Frazer refers it to the sixth arch.

The *muscle mass* of the mandibular arch forms the *tensor tympani*, the *tensor palati* and the *muscles of mastication*, including the mylo-hyoid and the anterior belly of the digastric (all supplied by the mandibular nerve). The tensor tympani retains its attachment to the skeletal element of the arch, but the muscles of mastication transfer their attachment to the mandible. The muscles of the hyoid arch for the most part migrate widely from their original position, but they retain their nerve-supply from the facial nerve. The *stapedius*, the *stylo-hyoid* and the *posterior belly of the digastric muscle* retain their attachment to the skeletal element of the arch, but the *muscles of facial*

Fig. 131.—The head and neck of a human embryo, eighteen weeks old, with Meckel's cartilage and the hyoid bar exposed. (After Kölliker.)



expression, the *platysma*, the *auricular muscles* and the *occipito-frontalis* (*epicranius*) lose all connexion with it. Their migration is facilitated by the obliteration of the first cleft and pouch in their ventral parts.

The muscle masses of the remaining arches form the *muscles of the pharynx, soft palate* and *larynx*. The *stylo-pharyngeus* can be attributed definitely to the third, the *cricothyroid* to the fourth and the remaining laryngeal muscles to the sixth arch, but the precise origin of the constrictor muscles and the muscles of the soft palate is uncertain.

Entodermal derivatives.—The description of the entodermal derivatives of the visceral arches and pharyngeal pouches is equivalent to the description of the development of the mouth, pharynx and larynx, and will therefore be considered later (p. 162).

THE LOCOMOTOR APPARATUS

The limbs.—In the fifth week the limbs appear as small elevations or buds from a slight lateral ridge at either side of the trunk (figs. 256, 257). Prolongations from several primitive segments extend into each bud, and carry with them the anterior primary rami of the corresponding spinal nerves ; the nerves supplying the limbs indicate the number of primitive segments which contribute to their formation—the upper limb being derived from seven, viz. fourth cervical to second thoracic inclusive, and the lower limb from ten, viz. twelfth thoracic

* Professor E. Fawcett. *Proceedings of the Anatomical Society of Great Britain and Ireland*, 1916.

to fourth sacral inclusive. The axial part of the mesenchyme of the limb-bud condenses and is converted into its cartilaginous skeleton, and by the ossification of this the bones of the limbs are formed. The musculature of the limbs is developed *in situ* from the mesoderm which surrounds the developing skeletal elements, and such muscles as the latissimus dorsi, which possess an extensive attachment to the axial skeleton in the adult, gain that attachment secondarily during intra-uterine life, as the result of active migration. The limbs are at first directed tailwards nearly parallel to the long axis of the trunk (fig. 133); by the end of the sixth week their long axes are at right angles to that of the trunk, and the three chief divisions of each limb are marked off by furrows—arm, forearm, and hand in the upper limb; thigh, leg, and foot in the lower (fig. 134). The future *flexor* surface of the limb is directed ventrally; the *extensor* surface, dorsally; one border (the *pre-axial*) looks towards the cephalic end of the embryo, and the other (the *post-axial*) towards the caudal end. The lateral epicondyle of the humerus, the radius, and the thumb lie along the preaxial border of the upper limb; the medial epicondyle of the femur, the tibia, and the big toe along the corresponding border of the lower limb. The limbs next become adducted and flexed on the trunk and, during this process, they undergo a rotation or torsion through an angle of 90° around their long axes, the upper limb being rotated in a lateral and the lower limb in a medial direction. As a consequence of this rotation the pre-axial (radial) border of the fore-limb is directed laterally, and the pre-axial (tibial) border of the hind-limb medially; thus the flexor surface of the fore-limb is turned forwards, and that of the hind-limb backwards. The pre-axial part is derived from the cephalic primitive segments, the post-axial from the caudal primitive segments of the limb-bud; and this explains, to a large extent, the cutaneous innervation of the adult limb, the nerves of the higher segments being distributed along the pre-axial (radial or tibial), and those of the lower segments along the post-axial (ulnar or fibular) border of the limb.

FIG. 132.—Diagram indicating the segments concerned with the formation of the upper limb-bud.

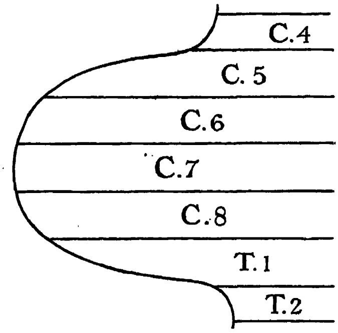
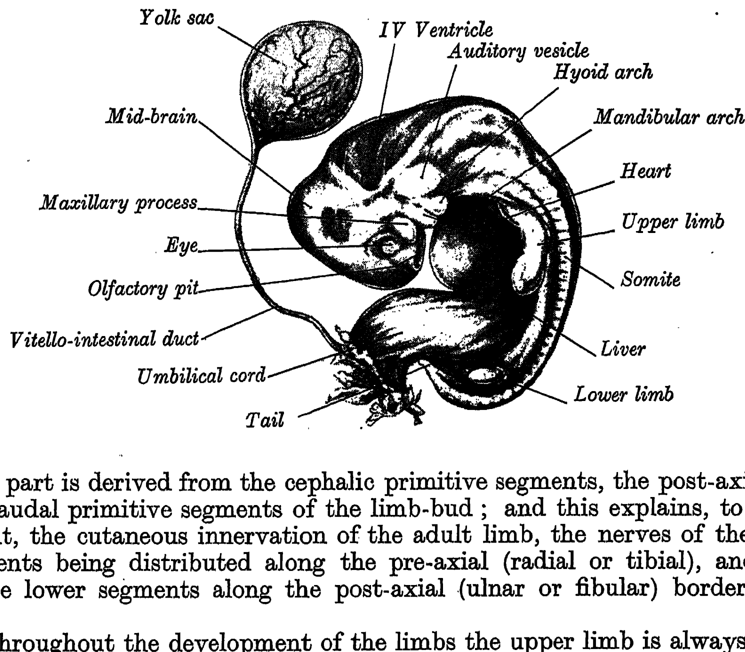


FIG. 133.—A human embryo about 9 mm. long. (Drawn from a stereoscopic photograph.)



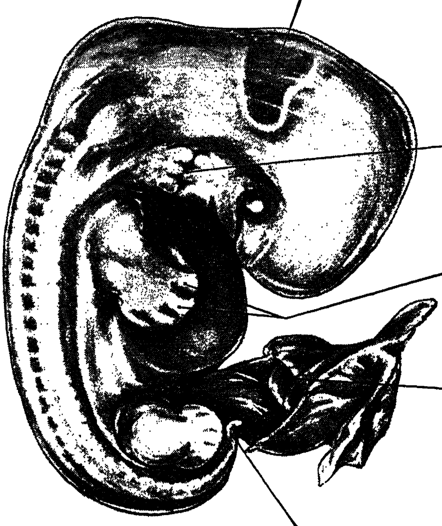
Throughout the development of the limbs the upper limb is always a little in advance of the lower limb. The foot and hand resemble each other closely at first, each being represented by a plate-like enlargement at the extremity of the bud. The mesenchymal core of the peripheral part of the plate becomes

condensed to outline the digits, and the thinner, intervening areas break down from the circumference towards the centre. This process may be carried out incompletely or it may be prematurely arrested, and in such cases varying degrees of *webbing of the fingers* or *toes* are present at birth.

The ossification of the limb-bones is described along with the description of the individual bones.

The **joints**.—The mesenchyme from which the different parts of the skeleton are formed shows no differentiation at first into masses corresponding with the individual bones; thus, continuous cores of mesenchyme form the axes of the limb-buds and a continuous column of mesenchyme the future vertebral column. The first indications of the differentiation of the bones and joints are circumscribed condensations of the mesenchyme; these condensed parts become chondrified and finally ossified to form the bones of the skeleton. The inter-

FIG. 134.—A human embryo about 15 mm. long. (Drawn from a stereoscopic photograph.)



vening non-condensed portions consist at first of undifferentiated mesenchyme, which may be converted into fibrous tissue as in the case of the skull bones, a fibrous joint being the result; or it may become partly fibrocartilaginous, in which case a cartilaginous joint is formed; or it may become looser in texture, a cavity ultimately appearing in its midst, while the cells lining the sides of this cavity form a synovial stratum, and thus a synovial joint is developed; in some synovial joints portions of the mesenchyme persist and form articular discs.

The tissue surrounding the original mesenchymal core forms fibrous sheaths for the developing bones (perichondrium and periosteum) which are continued between the ends of the bones over the synovial strata as the capsular ligaments of the joints. These capsules are not of uniform thickness, and specially strengthened bands—the precursors of ligament—can be recognised in them. This, however, is not the only method of formation of ligaments. In some cases by modification of, or derivation from, the tendons surrounding the joint, additional ligamentous bands are provided to strengthen the articulations.

The **muscles**.—With the exception of certain muscles of the head and neck which are developed from the mesodermal cores of the visceral arches (p. 100), and the muscles of the limbs, which develop *in situ* from the mesoderm of the limb-buds (p. 101), all the *voluntary muscles* of the body are derived from the myotomes (p. 65). Typically, each myotome divides into a dorsal and a ventral portion. The former takes up its position on the dorsilateral aspect

of the vertebral column and is innervated by the posterior primary ramus of the corresponding spinal nerve ; the cells of the latter migrate ventrally into the body wall or somatopleure and are innervated by the corresponding anterior primary ramus. In fishes these two primary subdivisions of the myotomes are separated from each other by the transverse processes of the vertebræ and a fibrous septum which extends from them to the lateral line. The pre-muscle masses, derived from the myotomes, may split longitudinally or tangentially, and the portions so derived may remain separate, e.g. the intercostal muscles, or they may fuse with the corresponding portions of adjoining myotomes, e.g. the external and internal oblique muscles and the transversus. In mammals the derivatives of the ventral portions of the myotomes may subsequently migrate so as to cover derivatives of the dorsal portions, but, as their nerve supply is determined at a very early stage, they carry their nerves with them as they migrate. As a result such muscles as the serratus posterior, superior and inferior, which are attached to the vertebral spines and cover the sacrospinalis, are supplied by anterior primary rami because they have been derived from the ventral portions of certain myotomes and have secondarily acquired their adult position and vertebral attachment. Numerous examples could be cited, but those already given will suffice to suggest others.

The muscles of the orbit and the muscles of the tongue require special mention. The hypoglossal nerve, as will be pointed out later (p. 1031), is a compound nerve and is serially homologous with the anterior nerve roots of the spinal nerves. Its inclusion within the skull is secondary. The myotomes of the corresponding somites, probably four in number, migrate from their original site into the tongue, carrying their nerve supply with them.

No mesodermic somites have yet been observed in the head region of the human embryo, but, on the evidence of comparative anatomy, it seems probable that a large number of somites, seven or more, originally developed in this situation. Of the corresponding myotomes, however, portions of only three persist, and they form the muscles supplied by the oculomotor, trochlear and abducent nerves.

In man and the higher vertebrates many of the derivatives of the myotomes degenerate and some disappear entirely. Others are converted into fibrous tissue, which may take the form of aponeuroses (e.g. the aponeuroses of the abdominal muscles) or ligaments (e.g. the sacrotuberous ligament).

The involuntary muscles are derived from the mesoderm of the splanchnopleure and develop *in situ*.

THE SKIN AND ITS APPENDAGES

The epidermis, hairs, nails, sebaceous and sudoriferous glands are developed from the ectoderm, the corium or true skin from the mesoderm. The ectoderm at first consists of a single stratum of cells, but in the sixth week two strata can be recognised, a superficial, named the *epitrichium*, consisting of flat cells, the nuclei of which stain readily, and a deep, named the *stratum germinativum*, consisting at first of cubical cells, but later of columnar. By multiplication and differentiation of the cells of the stratum germinativum the different layers of the epidermis are developed. Towards the end of the third month the mesoderm condenses to form the corium, and at about the same time the subcutaneous areolar tissue is differentiated ; in the fourth month the dermal papillæ begin to make their appearance. A considerable desquamation of the epidermis takes place, and this desquamated epidermis, mixed with sebaceous secretion, constitutes the *vernix caseosa*, with which the skin is smeared during the last three months of fœtal life.

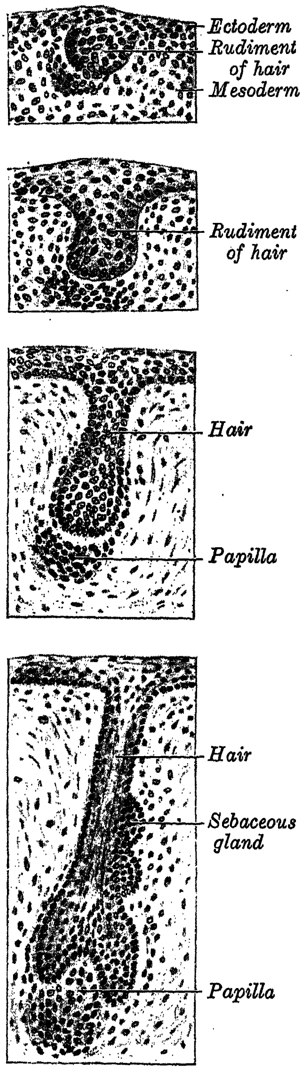
The *hairs* (fig. 135) originate as thickenings of the epidermis which grow obliquely downwards as solid buds into the corium, each bud consisting of an outer stratum of columnar cells and a core of polygonal cells. The deep end of each bud expands to form the hair-bulb, which is moulded over a papilla of condensed mesoderm. The cells of the hair-bulb proliferate and form a cone of cells, from which the scapus or shaft of the hair and its inner sheath are developed ; the hairs gradually lengthen by growth at the hair-bulb, and ultimately project on the surface.

The *sebaceous glands* originate as lateral outgrowths from the sides of the hair-buds, and, pushing their way into the mesenchyme, divide into three or four oval or flask-shaped alveoli, the lining cells of which are derived from the stratum germinativum.

The rudiments of the *sudoriferous* or *sweat glands* make their appearance on the palms

of the hands and soles of the feet in the fourth month, and closely resemble the rudiments of the hairs, each beginning as a solid downgrowth of the ectoderm. The ectodermal downgrowth lengthens, and its deeper part coils on itself and forms the body of the gland. A lumen is developed in the downgrowth about the seventh month of intra-uterine life, and opens on the surface by a duct which is lined with two layers of cells. In the secreting part of the gland the outer layer of cells is modified to form a stratum of smooth muscle-fibres which lies between the epithelium of the gland and the basement-membrane. Many sudoriferous glands arise as ectodermal downgrowths from the superficial portions of the hair-follicles and later acquire independent openings on the surface of the skin.

FIG. 135.—Successive stages in the development of a hair.



The rudiments of the *nails* can be seen in embryos of about 4·5 cm. in length, and appear as *primary nail-fields* of ectoderm on the dorsal surfaces of the distal phalanges of the digits. At the proximal end and sides of each nail-field the epidermis is invaginated to form the nail-folds, while the distal end, which will ultimately form the free end of the nail, is bounded by a shallow groove. The nail is developed from the posterior nail-fold and consists of modified stratum lucidum. The stratum corneum covers the nail and forms the *eponychium*; this disappears from the surface of the nail, with the exception of a narrow fold which overlaps the proximal part of the lunule.

The *mammary gland* may be looked upon as a collection of greatly modified sudoriferous glands; the epithelial lining of its ducts and alveoli is derived from the ectoderm, its supporting connective tissue from the mesenchyme. On each side of the ventral surface of young embryos a thickened band of ectoderm, termed the *milk-ridge*, extends obliquely from the axilla to the inguinal region, and in some of the lower mammals mammæ are developed at intervals along this ridge; in man, no definite ridge is found, and only one mamma, as a rule, is developed on each side of the median plane, but supernumerary mammæ or nipples are sometimes found above or below the fully developed gland.

The rudiment of the mammary gland appears as a thickening and subsequent ingrowth of the ectoderm; from this ingrowth fifteen or twenty solid cords branch off, each cord representing a future lactiferous tubule and lobe of the gland. The deep ends of the cords subdivide in the mesenchyme and form the alveoli of the gland. The region where the ectodermal thickening occurred is subsequently raised to form the nipple, and about the time of birth the tubules and alveoli become canalised. At the age of puberty, and in a greater degree towards the end of pregnancy, a marked enlargement of the gland, and a development of additional lobules and alveoli, take place.

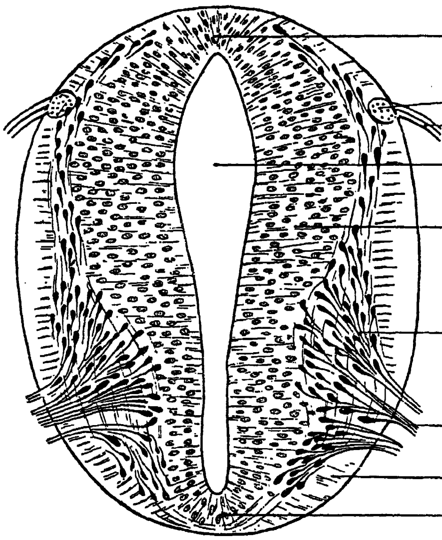
THE DEVELOPMENT OF THE NERVOUS SYSTEM AND SENSE-ORGANS

The appearance of the medullary plate and its further differentiation into a median neural groove limited on each side by neural folds which fuse with each other during the fourth week to form a neural tube, have already been

described (p. 60). The cephalic end of the neural tube develops into the brain and its ventricles, and the remainder of the tube forms the spinal cord and its central canal.

The **spinal cord.**—At the time when the neural tube is closing the cells in the neural folds are proliferating so rapidly that their cell boundaries are lost, and they form a syncytium in which the nuclei are closely packed together. On the outside and on the inside of the tube the syncytium condenses to form an *outer* and an *inner limiting membrane.* As growth proceeds it becomes possible to distinguish an inner or *ependymal layer*, an intermediate or *mantle layer*, and an outer or *marginal layer* (fig. 136). The cells of the inner layer give

FIG. 136.—A transverse section through the spinal cord of a human embryo four weeks old. (His.)



rise to cells which migrate into the mantle layer, and also to the ependymal cells which subsequently line the central canal. The cells of the intermediate or mantle layer are of two varieties, termed *spongioblasts* and *neuroblasts*. The former give origin to neuroglia and the latter to nerve cells. Increase in the number of cells in the mantle layer is brought about partly by the subdivision of its constituent cells and partly by the migration into it of cells derived from the ependymal layer. The outer or marginal layer consists of a non-nucleated protoplasmic syncytium and forms a framework for the various tracts by which it is subsequently invaded. The roof- and floor-plates of the neural tube remain thin, and their cells only contribute to the formation of ependyma.

The nerve-cells are large and, at first, round or oval in shape. Soon they become pear-shaped, and the narrow end of the cell becomes drawn out to form the axis cylinder process or axon. These cells are therefore primarily unipolar, but further differentiation leads to the development of dendritic processes, and they become typical multipolar nerve-cells. In the developing spinal cord the nerve-cells occur in small clusters, and two or more of them may be connected to one another by their apical processes. It is uncertain whether such groups represent nerve-cells undergoing rapid division, or whether the fusion of the developing axons is secondary. The former seems the more probable explanation.

The spongioblasts are connected to one another by strands of the syncytium in which numerous branching fibrils develop, and as the neuroglia cells mature the syncytium becomes condensed around them so that they assume their characteristic spider-like appearance with multiple processes proceeding from each cell.

At first the neural tube is oval in outline and its lumen is narrow and slit-

like (fig. 136). The lateral walls rapidly become thicker, but the *roof-plate* and the *floor-plate* remain thin and do not share in this cellular proliferation. As its lateral walls thicken the lumen widens in its dorsal part and presents a somewhat lozenge-shaped appearance on cross-section (fig. 138, A). The widest part of the canal subdivides each lateral wall into a ventral or *basal lamina* and a dorsal or *alar lamina*. This separation is fundamental and indicates a functional difference, for the cells in the basal lamina become the motor cells of the anterior and lateral grey columns, while the cells of the alar lamina form neurones on the afferent, sensory, pathways. The widening of the canal is due to the development of a longitudinal *sulcus limitans* on the inner wall on each side. At its caudal end the canal exhibits a fusiform dilatation which is known as the *terminal ventricle*.

The cells of the ependymal layer are closely packed at this stage and tend to arrange themselves in radial columns. The cells of the mantle layer are more loosely arranged, and they increase in number at first in the region of the basal lamina. This enlargement outlines the *anterior column* of the grey matter and it causes a forward projection on each side of the median plane, the floor-plate remaining at the bottom of the shallow groove so produced. As growth proceeds, these enlargements, further increased by the development of the anterior white columns, encroach on the groove until it becomes converted into the slit-like anterior median fissure of the adult spinal cord (fig. 138, A and B). The axons of the nerve-cells in the anterior grey column traverse the marginal zone and emerge on the anterolateral aspect of the spinal cord as the *anterior nerve roots*.

In the thoracic and upper lumbar regions the cells of the mantle layer in the dorsal part of the basal lamina outline a *lateral column*. The axons of its cells join the emerging anterior nerve roots and pass through white rami communicantes to the ganglia of the sympathetic trunk to be distributed to the viscera and blood-vessels. At the same time a lateral column is laid down in the mid-sacral region also, and gives origin to the parasympathetic fibres which form the pelvic splanchnic nerves (p. 1138).

As the anterior and lateral grey columns assume their final form the cells in the ventral part of the ependymal layer gradually cease to proliferate, and the layer becomes reduced in thickness until it ultimately forms the single-layered ependyma. The *posterior column* is somewhat later in its development, and, as a result, the ependymal layer is for a time much thicker in the alar lamina than it is in the basal lamina.

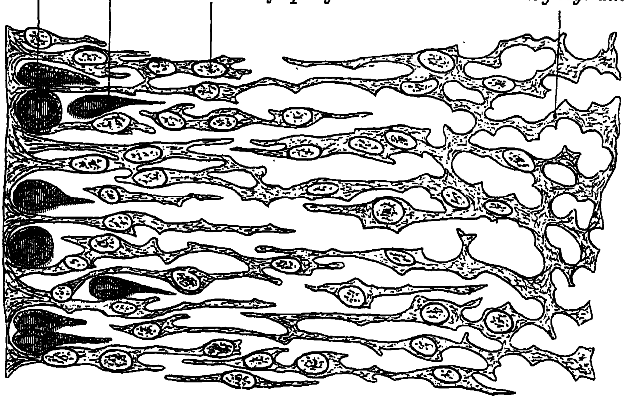
While the columns of grey matter are being defined, the dorsal portion of the central canal becomes narrow and slit-like, and its walls come into apposition and fuse with each other (fig. 138). In this way the central canal becomes considerably reduced in size and somewhat triangular in outline.

About the end of the fourth week nerve-fibres appear in the marginal layer. The first to develop are the short intersegmental fibres from the neuroblasts in the mantle zone, and the fibres of the posterior roots of the spinal nerves which pass into the spinal cord from the cells of the spinal ganglia. By the sixth week the fibres of the posterior roots of the spinal nerves form a well-defined *oval bundle* in the peripheral part of the alar lamina ; this bundle increases in size, and spreading towards the median plane forms the rudiment of the posterior white column. As the posterior white columns increase in thickness, their opposed medial surfaces come into contact with each other, and the *posterior median septum*, which subsequently separates them, is neuroglial in origin. The long intersegmental fibres begin to appear about the third month, and the cerebrospinal fibres about the fifth month. All nerve-fibres are at first destitute of medullary sheaths, and different groups of fibres receive their sheaths at different times, e.g. the anterior and posterior nerve-roots are medullated about the fifth month, the cerebrospinal fibres after the ninth month. The source of the myelin is uncertain. It has been regarded as a modification of the outermost part of the axis cylinders and, in the case of the peripheral nerves, its formation has been attributed to the cells of the nucleated neurolemma sheaths. Recently, it has been suggested that the myelin has an extraneural origin and is derived from the blood-stream, being deposited round the axons in some manner unknown.

The cervical and lumbar enlargements appear simultaneously with the development of the limb-buds.

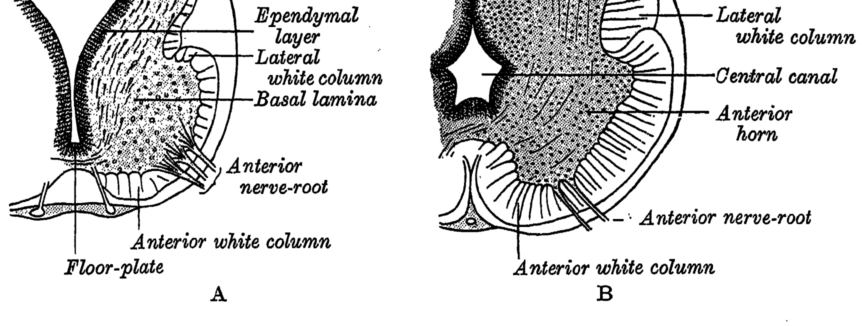
In early fœtal life the spinal cord occupies the entire length of the vertebral canal, and the spinal nerves pass outwards at right angles. After the embryo

Fig 137.—A transverse section through the spinal cord of a human embryo at the beginning of the fourth week. (After His.) The left edge of the figure corresponds to the lining of the central canal.



has attained a length of 30 mm. the vertebral column begins to grow more rapidly than the spinal cord, which gradually assumes a higher position within the vertebral canal. The principal part of this upward migration occurs during the first half of intra-uterine life. By the twenty-fifth week of intra-uterine life the terminal ventricle of the spinal cord (p. 893) has ascended from

Fig. 138.—Transverse sections through the spinal cord of a human embryo. A, about six weeks old. B, about three months old. (His.)



the level of the second coccygeal vertebra to that of the third lumbar vertebra, or a distance of nine segments, and there remain but two segments before the adult position is reached (Streeter *). As the migration upwards commences, the caudal end of the terminal ventricle, which has become adherent to the overlying ectoderm, remains *in situ*, and the walls of the ventricle and its

* George L. Streeter, *American Journal of Anatomy*, vol. 25, 1919.

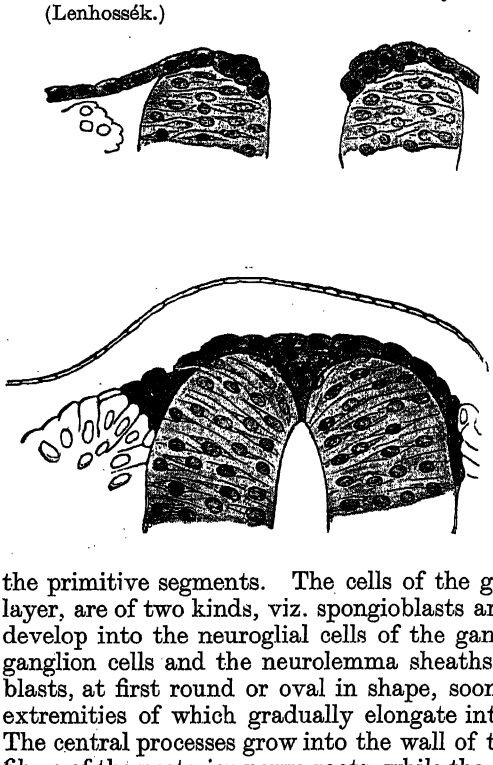
covering pia mater become drawn out to form a delicate filament, termed the *filum terminale*. The separated portion of the terminal ventricle persists for a time but it disappears as a rule before birth. It does, however, occasionally give rise to congenital cysts in the neighbourhood of the coccyx.

The spinal nerves.—Each spinal nerve is attached to the spinal cord by an anterior root and a posterior root.

The fibres of the anterior roots are formed by the axons of the neuroblasts which lie in the ventral and lateral parts of the mantle layer ; these axons pass out through the overlying marginal layer into the myotomes of the primitive segments, and are ultimately aggregated to form the anterior nerve-roots (fig. 138).

The fibres of the posterior roots are developed from the cells of the spinal ganglia. Before the neural groove is closed to form the neural tube a ridge of ectodermal cells termed the *ganglion-ridge* or *neural crest* (fig. 139) appears along the prominent margin of each neural fold. When the folds meet in the median plane the two ganglion-ridges fuse and form a wedge-shaped area along the line of closure of the tube. Opposite the primitive segments the cells of this area proliferate rapidly to form a series of oval-shaped masses, which migrate for a short distance in a lateral and ventral direction. From the ventral part of each mass a small portion is detached to form sympathochromaffin cells (p. 124), while the remainder is converted into a spinal ganglion. The spinal ganglia are arranged symmetrically at the sides of the neural tube and, except in the region of the tail, are equal in number to the primitive segments. The cells of the ganglia, like the cells of the mantle layer, are of two kinds, viz. spongioblasts and neuroblasts. The spongioblasts develop into the neuroglial cells of the ganglia, the nucleated capsules of the ganglion cells and the neurolemma sheaths of the spinal nerves. The neuroblasts, at first round or oval in shape, soon assume the form of spindles the extremities of which gradually elongate into central and peripheral processes. The central processes grow into the wall of the neural tube, and constitute the fibres of the posterior nerve-roots, while the peripheral processes grow forwards to mingle with the fibres of the anterior root in the spinal nerve. As development proceeds the original bipolar form of the cells in the spinal ganglia changes ; the two processes become approximated until they ultimately arise from a single stem in a T-shaped manner. The bipolar form is retained in the retina and in the ganglia of the auditory nerve. Some observers hold that the T-form is derived from the branching of a single process which grows out from the cell.

FIG. 139.—Two stages in the development of the neural crest in the human embryo. (Lenhossék.)

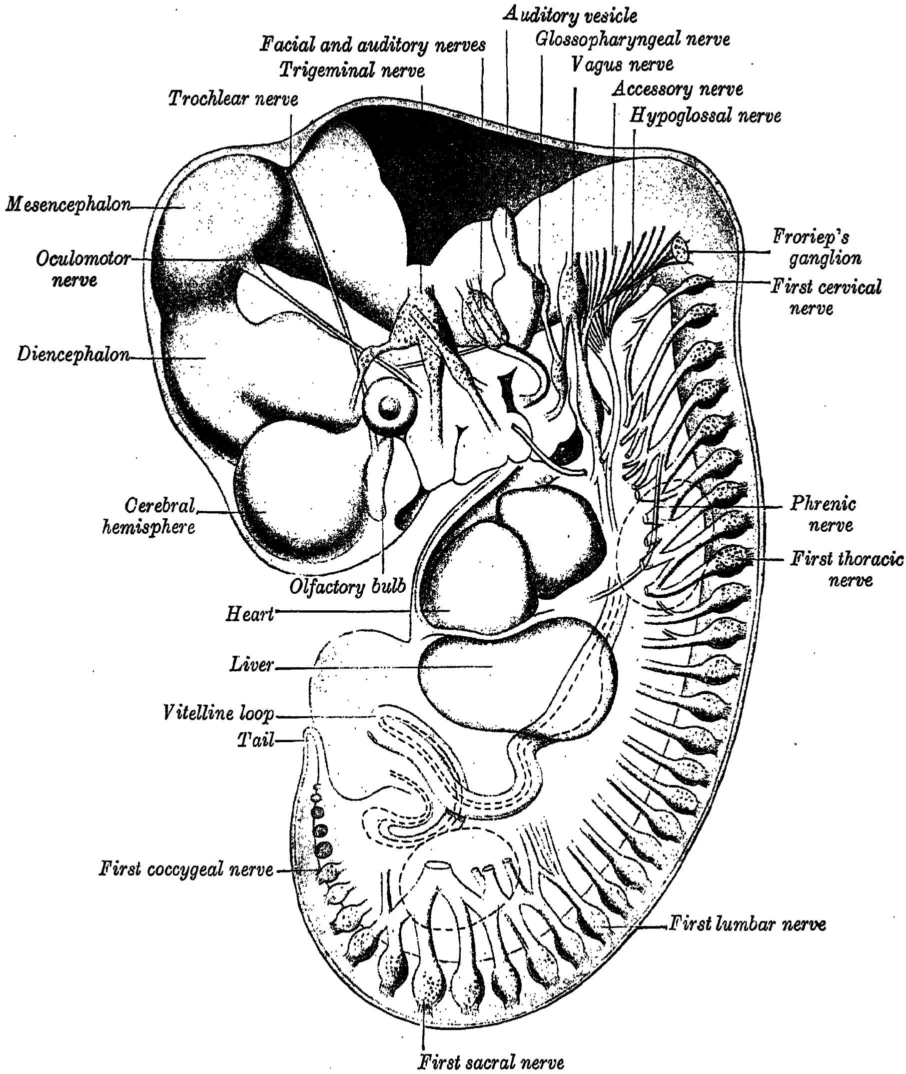


The precise manner in which a motor nerve-cell establishes contact with its effector is still uncertain. On the whole, the balance of the evidence, both embryological and experimental, supports the view that the axon grows out from the body of the cell and finds its way to the effector, and that the processes of the sensory nerve-cells develop in the same way. On the other hand, many embryologists maintain that, from the earliest stages of development, the ectodermal motor cells are in direct connexion with the mesodermal muscle cells by means of protoplasmic bridges and that this connexion, though it may undergo considerable lengthening, is never lost. Harrison * has carried out a long series

* R. G. Harrison, *American Journal of Anatomy*, 1906.

of experiments, chiefly on amphibian larvæ, which all tend to support the view that the axons grow out actively from the nerve-cells. The same observer and others have succeeded in culturing nerve-cells *in vitro*, and they have found that in the complete absence of other tissues the cells give rise to long processes which, so far as can be ascertained, are identical with axis cylinder processes. The opponents of this view depend mainly on histological observations. Graham Kerr * has traced back the development of the motor nerve-trunk

FIG. 140.—A human embryo 10·2 mm. long, showing the peripheral nerves. (After a reconstruction by His.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



The abducent nerve is not labelled, but is seen passing forwards to the eye deep to the mandibular and maxillary nerves.

in *Lepidosiren paradoxa* to a period in which it is represented by a bridge of soft granular protoplasm connecting the spinal cord and myotome at a stage when these structures are in close apposition. As the myotome is pushed outwards it remains connected with the spinal cord by the ever-lengthening strand of nerve, which soon loses its granular protoplasmic character and assumes a fibrillated appearance. Cameron and Milligan † hold that in early embryonic life the cell-elements of the sense-epithelium of the auditory vesicle are connected with those of the hind-brain by a continuous tract of nucleated protoplasm

* J. Graham Kerr, *Transactions of the Royal Society of Edinburgh*, vol. xli. part i. 1903-4.

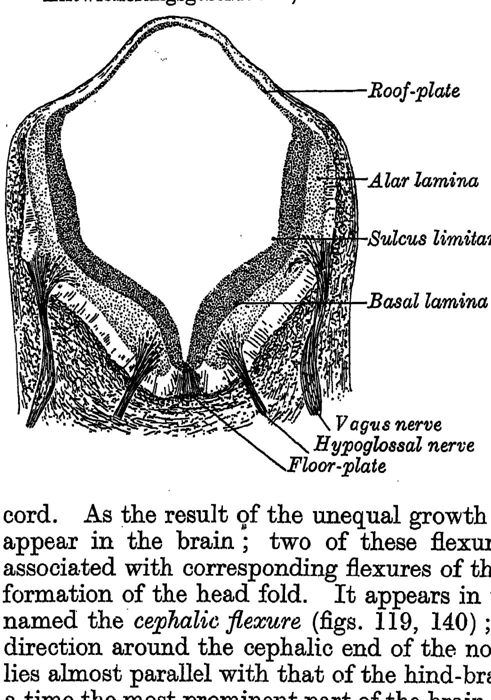
† "The development of the auditory nerve in vertebrates," *Journal of Anatomy and Physiology*, vol. xliv.

(syncytium) which is never severed. This syncytium, at first undifferentiated, becomes fibrillated longitudinally to form a continuous tract of nerve-fibres (the future auditory nerve) uniting the sense-epithelium of the auditory organ with the hind-brain.

Frances M. Ballantyne * believes that the posterior roots of the spinal nerves are similarly developed, the rudiments of the spinal ganglia being from the first connected to the spinal cord by protoplasmic bridges which are never severed, but become fibrillated and lengthen out as the embryo grows.

The cells which form the neurolemma sheaths of the peripheral nerves have been ascribed to a variety of sources. Harrison † excised the neural crest in young amphibian larvæ and discovered that the motor fibres derived from the corresponding portion of the neural tube developed as naked axons. Later, however, these fibres acquired a neurolemma sheath, the constituent cells migrating from the wall of the neural tube. He came to the conclusion that the sheaths are ectodermal in origin, formed partly from the cells of the neural crest and partly from the cells of the neural tube.

Fig. 141.—A transverse section through the medulla oblongata of a human embryo, 10·2 mm. long. × 32. (From Kollmann's Entwickelungsgeschichte.)



The brain.—Prior to the closure of the neural tube the neural folds become expanded considerably in the head region to outline the brain (fig. 79). Subsequent to its closure these expansions form the three primary cerebral vesicles (fig. 144). These are marked off from each other by constrictions, and are named the *rhombencephalon* or *hind-brain*, the *mesencephalon* or *mid-brain*, and the *prosencephalon* or *fore-brain*—the first being continuous with the spinal cord. As the result of the unequal growth of its different parts three flexures appear in the brain; two of these flexures are concave ventrally and are associated with corresponding flexures of the head. The first is caused by the formation of the head fold. It appears in the region of the mid-brain, and is named the *cephalic flexure* (figs. 119, 140); the fore-brain bends in a ventral direction around the cephalic end of the notochord and fore-gut until its floor lies almost parallel with that of the hind-brain (fig. 140). The mid-brain is for a time the most prominent part of the brain, since its dorsal surface corresponds with the convexity of the flexure. The second bend appears at the junction of the hind-brain and spinal cord, and is termed the *cervical flexure* (fig. 140). It increases from the fifth week to the end of the seventh, when the hind-brain forms nearly a right angle with the spinal cord; after the seventh week erection of the head takes place and the cervical flexure diminishes and disappears. The third bend is named the *pontine flexure* (fig. 144), because it is found in the region of the future pons. It differs from the other two in that (*a*) its convexity is forwards, and (*b*) it does not affect the head.

The lateral walls of the hind-brain and mid-brain, like those of the spinal cord, are divided into dorsal or alar and ventral or basal laminæ (fig. 142) by the upward continuation of the limiting sulci of the spinal cord.

The rhombencephalon or hind-brain.—By the time the cephalic flexure appears, the hind-brain exceeds in length the combined lengths of the other two brain vesicles. At its cephalic end it exhibits a constriction termed the *isthmus rhombencephali* (fig. 144, Isthmus), which is best seen when the brain is viewed from the dorsal aspect. Ventrally it is separated from the dorsal wall of the primitive pharynx only by the notochord, the two dorsal aortæ, and a small

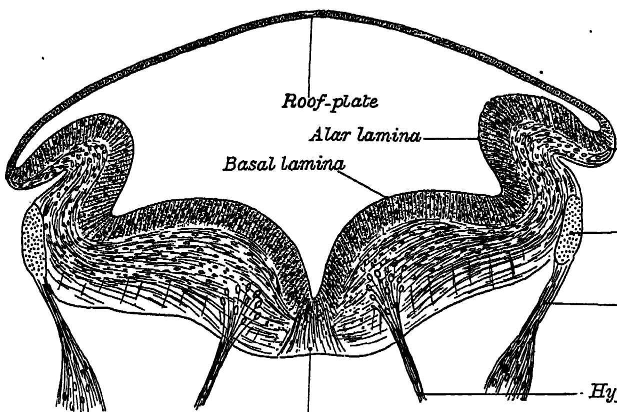
* "The continuity of the vertebrate nervous system," *Transactions of the Royal Society of Edinburgh*, vol. liii. p. 663, 1925.

† R. G. Harrison, *Journal of Comparative Neurology*, 1924.

amount of mesenchyme, and on each side it is closely related to the dorsal ends of the visceral arches (fig. 119).

The formation of the pontine flexure throws a strain on the thin, epithelial roof-plate, which becomes stretched and widened, the maximum increase in width corresponding to the region of maximum convexity, so that the outline of the roof-plate becomes rhomboidal in form. At the same time, the lateral walls fall outwards away from each other (fig. 142) and the cavity of the hind-brain, which subsequently forms the fourth ventricle, becomes flattened and somewhat triangular on cross-section. The pontine flexure becomes more and more acute until, at the end of the second month, the alar and basal laminæ of its cephalic (metencephalon) and caudal (myelencephalon) slopes are opposed

Fig. 142.—A transverse section through the medulla oblongata of a human embryo. (After His.)



to each other and, at the same time, the lateral angles of the cavity become drawn out to form the lateral recesses of the fourth ventricle.

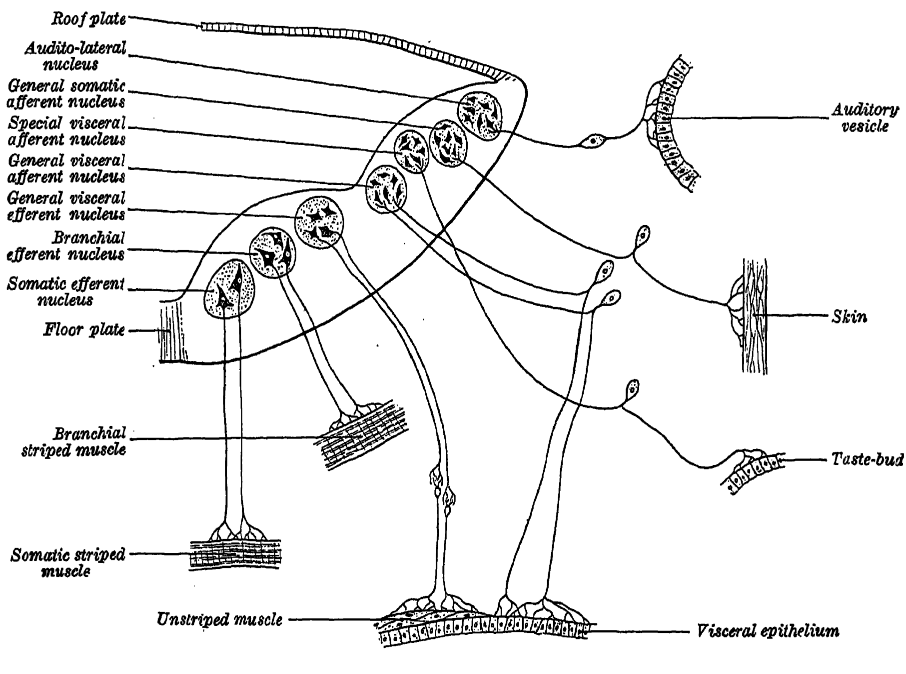
About the end of the fourth week, when the pontine flexure is beginning to be discernible, a series of six transverse grooves appears in the basal lamina of the hind-brain. These are termed the *rhombic grooves* and they bear a very definite relationship to the motor nuclei of certain of the cranial nerves. The first two overlie the nucleus of the trigeminal nerve; the third overlies the nucleus of the facial nerve, the fourth that of the abducent nerve, the fifth that of the glossopharyngeal and the sixth that of the vagus nerve. These grooves, though transient, are constant in character but their significance is uncertain. They are probably associated with the appearance of the visceral arches, but the association of the fourth groove with the nucleus of the abducent nerve cannot be harmonised with this arrangement.

The differentiation of the lateral walls of the hind-brain into basal and alar laminæ has a similar significance to the corresponding differentiation in the lateral wall of the spinal cord, and ependymal, mantle and marginal layers are formed in the same way. The cells of the basal lamina are motor in function and they form three elongated, but interrupted, columns. The most ventral column is in line with the anterior grey column of the spinal cord and is destined for the supply of muscles which are myotomic in origin. It is represented in the caudal part of the hind-brain, where it forms the nucleus of the hypoglossal nerve, and it reappears at a higher level as the nucleus of the abducent nerve, both of which are termed *somatic efferent nuclei.* The intermediate column, which is only represented in the upper part of the spinal cord, is destined for the supply of the musculature derived from the branchial arches. It is interrupted also, but the lower part, which gives fibres to the eleventh, tenth and ninth cranial nerves, forms the elongated nucleus ambiguus. At higher levels this column gives origin to the motor nuclei of the facial and trigeminal nerves. These three nuclei are termed *branchial* (or *special visceral*)

efferent nuclei. The most dorsal column is represented in the spinal cord by the lateral grey column and, like it, is destined for the innervation of viscera. It is interrupted also, its large lower part forming the dorsal nucleus of the vagus and its higher part the upper and lower salivatory nuclei. These are termed *splanchnic*, or *general visceral, efferent nuclei.*

Similar interrupted columns are formed in connexion with the alar lamina and give-rise to *general visceral afferent, special visceral afferent, general somatic afferent* and *special somatic afferent* columns (fig. 143). These columns, like those of the basal lamina, are interrupted and broken up into nuclei, but, although they tend to, and may, retain their primitive position, in many instances they migrate from their site of origin—presumably in accordance with the principle of neurobiotaxis (p. 911).

FIG. 143.—Diagram of a transverse section through the developing hind-brain to show the relative positions of the nuclei of the different varieties of nerve components.



The caudal slope of the hind-brain constitutes the *myelencephalon,* which develops into the medulla oblongata. The nuclei of the ninth, tenth, eleventh and twelfth cranial nerves develop in the situations already indicated, and afferent fibres from the ganglia of the ninth and tenth nerves form an oval bundle in the marginal zone in the region of the alar lamina (fig. 142). The dorsal edge of the alar lamina throughout the rhombencephalon gives attachment to the thin expanded roof-plate and is termed the *rhombic lip.* As the walls of the rhombencephalon fall outwards, the rhombic lip forms a lateral edge (fig. 143) which becomes folded over the adjoining area (fig. 142). According to the generally accepted view it later becomes adherent to this area, and the cells of the rhombic lip migrate actively into the marginal zone of the basal lamina. In this way the oval bundle of the tractus solitarius becomes buried beneath the surface. The cells which migrate from the rhombic lip are believed to give origin to the olivary and arcuate nuclei and the scattered grey matter of the formatio reticularis. While this migration is in progress the thin floor-plate is invaded by fibres which cross the median plane, and it becomes thickened to form the median raphe.

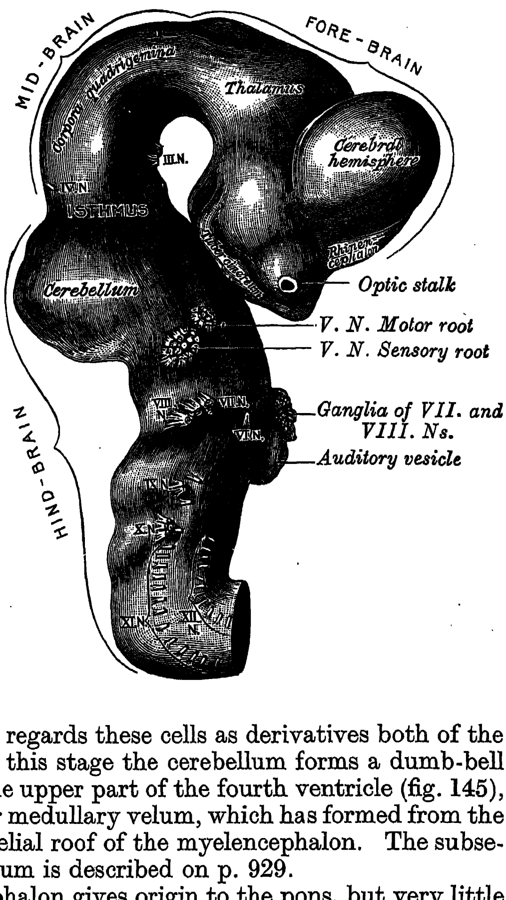
The lower part of the myelencephalon takes no part in the formation of the fourth ventricle, and, in its development, it closely resembles the spinal cord. The large nuclei, gracilis and cuneatus, are derived from the alar lamina, and

their efferent arcuate fibres play a large part in the formation of the median raphe.

About the fourth month the descending cerebrospinal fibres invade the ventral part of the medulla oblongata to form the pyramid and ascending fibres from the spinal cord, together with olivocerebellar and arcuate fibres, form the inferior cerebellar peduncle (restiform body).

The upper or headward slope of the hind-brain is termed the *metencephalon* and from it both the cerebellum and the pons are developed. Prior to the formation of the pontine flexure the alar laminæ of the metencephalon are parallel with one another. Subsequent to its formation the roof-plate of the hind-brain becomes rhomboidal and the alar laminæ of the metencephalon lie obliquely, being close to one another at the headward end of the fourth ventricle, but widely separated in the region of its lateral angles. The accentuation of the pontine flexure approximates the upper angle of the ventricle to the lower, and the alar laminæ of the metencephalon now lie almost horizontally and in line with each other.

Fig. 144.—The brain of a human embryo about 10·2 mm. long. Right lateral surface. (From a model by His.)



While these changes are occurring the cells in the rhombic lip and dorsal part of the alar lamina of the metencephalon proliferate to form the rudiment of the cerebellum. Two rounded swellings are formed which, at first, project partly into the ventricle (fig. 146), and they form the rudimentary cerebellar hemispheres. The uppermost part of the roof of the metencephalon originally separates the two swellings, but it becomes invaded by cells which form the rudiment of the vermis. Frazer * regards these cells as derivatives both of the basal and of the alar laminæ. At this stage the cerebellum forms a dumb-bell shaped swelling stretched across the upper part of the fourth ventricle (fig. 145), continuous above with the superior medullary velum, which has formed from the isthmus, and below with the epithelial roof of the myelencephalon. The subsequent development of the cerebellum is described on p. 929.

The remainder of the metencephalon gives origin to the pons, but very little is known of the individual stages in the transformation. Ependymal, mantle and marginal zones are formed in the usual way, and the nuclei of the fifth, sixth and seventh nerves develop in the mantle layer. It is probable that the grey matter of the formatio reticularis is derived from the basal lamina and that of the nuclei pontis from the alar lamina by the active migration of cells from the rhombic lip. About the fourth month the pons is invaded by cerebropontine and cerebrospinal fibres, becomes proportionately thicker, and takes on its adult appearance.

The region of the *isthmus rhombencephali* undergoes a series of changes which are very difficult to interpret. As a result, the greater part of the region apparently becomes taken up into the caudal end of the mid-brain, only the roof-plate, in which the superior (anterior) medullary velum is formed, and the dorsal parts of the alar laminæ, which become invaded by the fibres of the

* J. Ernest Frazer, *Manual of Embryology*, 1931.

superior cerebellar peduncles, remaining as recognisable derivatives in the adult. Frazer * believes that during the earlier changes the cells of the basal lamina extend dorsally until they meet in the roof-plate, and intervene between the alar lamina and the interior of the tube. In this way he provides an explanation for the dorsal position of the superficial origin of the fourth nerves, which, although apparently emerging from the dorsal aspect of the isthmus, are in reality emerging from its morphological floor.† It should be noted, too, that originally the decussation of the two fourth nerves is placed on the hind-brain side of the isthmus, but as the growth changes occur it is displaced in a headward direction until it reaches its adult position. The same author considers that these changes are also responsible (1) for the movement in the same direction of the nucleus of the fourth nerve, whereby it comes to lie in the mid-brain, and (2) for the position of the mesencephalic nucleus of the fifth nerve, which is also a derivative of the isthmus rhombencephali. (See footnote on p. 945.)

Fig. 145.—The cerebellum of a fœtus in the fifth month. (From Kollmann's Entwickelungsgeschichte.)

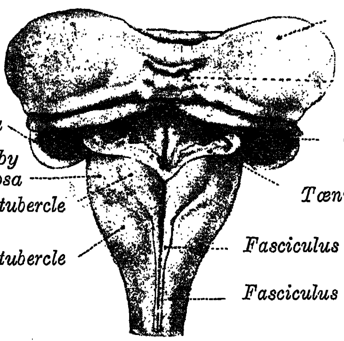
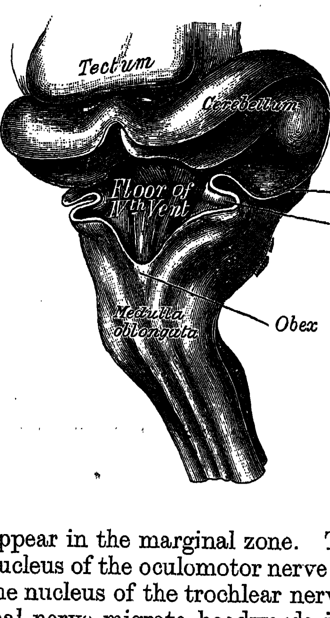


Fig. 146.—The hind-brain of a human embryo about three months old. Viewed from behind and partly from the right side. (From a model by His.)



The **mesencephalon** or **mid-brain** (figs. 140, 144, 146, and 147 to 151) exists for a time as a thin-walled tube enclosing a cavity of some size, and is separated by slight constrictions from the isthmus and from the fore-brain. Its cavity becomes relatively reduced in diameter, and in the adult brain it forms the aqueduct of the mid-brain. The basal laminæ of the mid-brain increase in thickness to form the cerebral peduncles, which are at first of small size, but enlarge rapidly after the fourth month, when their fibre-tracts begin to appear in the marginal zone. The cells of the basal lamina give origin to the nucleus of the oculomotor nerve and to the grey matter of the tegmentum, while the nucleus of the trochlear nerve and the mesencephalic nucleus of the trigeminal nerve migrate headwards into the mid-brain owing to the developmental changes which occur in the isthmus rhombencephali. The cells of the dorsal

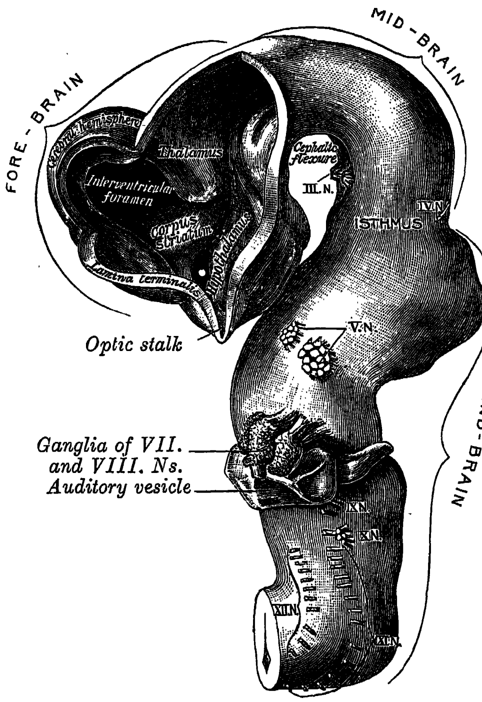
* J. Ernest Frazer, *Journal of Anatomy*, Oct. 1928, and *loc. cit.*

† Those who hold that the sulcus limitans is continued into the mid-brain, and has the same morphological value there as it has in the hind-brain and spinal cord, find it difficult to accept this explanation for the mode of behaviour of the trochlear nerves.

part of the alar laminæ proliferate and invade the roof-plate, which therefore becomes thickened and is later divided into corpora bigemina by a median groove. At its caudal end this groove becomes a median ridge, which persists in the adult as the frenulum veli. The corpora bigemina are later subdivided into corpora quadrigemina by a transverse furrow. The origin of the red nucleus, which is clearly defined at the end of the third month, is uncertain, but it is, on the analogy of the olivary nuclei of the medulla oblongata, formed probably by cells of the alar lamina which migrate in a ventrimedial direction.

The **prosencephalon** or **fore-brain.**—A transverse section through the early fore-brain shows the same parts as are displayed in similar sections of the spinal cord and medulla oblongata, viz. a pair of thick lateral walls connected by thin floor- and roof-plates. Moreover, each lateral wall is divided into a dorsal area and a ventral area separated internally by a furrow termed the *hypothalamic sulcus.* This sulcus ends anteriorly at the medial end of the optic stalk, and in the adult brain is retained as a slight groove extending backwards from the interventricular foramen to the aqueduct of the mid-brain.

FIG. 147.—The brain of a human embryo, about 10·2 mm. long. (From a model by His.)



At a very early period—in some animals before the closure of the cephalic part of the neural tube—two lateral diverticula termed the *optic vesicles* appear, one on each side of the fore-brain; for a time they communicate with the cavity of the fore-brain by relatively wide openings. The distal parts of the optic vesicles expand, while the proximal parts are reduced to tubular stalks termed the *optic stalks*; their further development is given on pp. 125 to 130. The fore-brain then grows forwards, and gives origin to two diverticula which rapidly expand to form two large pouches, one on each side. These diverticula subsequently form the cerebral hemispheres, and their contained cavities are the rudiments of the lateral ventricles; they communicate with the median part of the fore-brain cavity by relatively wide openings which ultimately form the interventricular foramen. The anterior part of the roof-plate of the fore-brain consists of a thin sheet termed the *lamina terminalis* (figs. 147, 150), which stretches from the interventricular foramen to the recess at the base of the optic stalk. The anterior part of the fore-brain, including the rudiments of the cerebral hemispheres, is named the *telencephalon,* and the posterior portion the *diencephalon*; both contribute to the formation of the third ventricle.

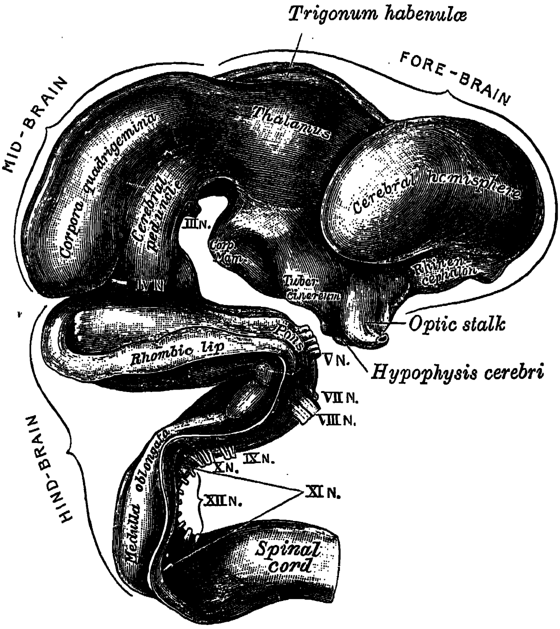
The *diencephalon.*—The thalamus and the metathalamus are developed from the dorsal area of the diencephalon. The *thalamus* (figs. 147 to 153) arises as a thickening which involves the anterior part of the dorsal area. Caudal to the thalamus, the lateral and medial geniculate bodies, which constitute the *metathalamus*, are recognisable at first as surface depressions. As the thalami enlarge they gradually narrow the wide interval between them into a slit-like cavity which forms the greater part of the third ventricle. After a time these medial surfaces come into contact and become adherent to each other over a variable area, the connexion constituting the *connexus interthalamicus* (*inter-*

mediate mass). The backward growth of the thalamus excludes the geniculate bodies from the lateral wall of the third ventricle.

At first the lateral aspect of the developing thalamus is separated from the medial aspect of the cerebral hemisphere by an extraneural cleft, but as growth proceeds the cleft becomes obliterated (p. 119) and the thalamus comes into intimate relationship with the corpus striatum. Later, with the development of the itinerant (projection) fibres of the neopallium, the thalamus becomes related to the internal capsule, which intervenes between it and the lateral part of the corpus striatum (lentiform nucleus).

Below (ventral) to the hypothalamic sulcus the lateral wall of the diencephalon forms a large part of the hypothalamus, including the lateral and posterior hypothalamic nuclei.

Fig. 148.—The brain of a human embryo, 13·6 mm. long. Right lateral aspect; the roof of the hind-brain has been removed. (From a model by His.)



The *epithalamus*, which includes the pineal body, the posterior commissure and the trigonum habenulæ, develops in association with the caudal part of the roof-plate and the adjoining portions of the lateral walls of the diencephalon. The pineal body arises as a hollow outgrowth from the roof-plate, immediately in front of the mesencephalon. Its distal portion becomes solid, but its proximal portion, or stalk, remains hollow, containing the recessus pinealis of the third ventricle. In many reptiles the pineal outgrowth is double. The anterior outgrowth (parapineal organ) develops into the pineal eye (p. 962) while the posterior outgrowth is glandular in character. It is the posterior outgrowth which is homologous with the pineal body in man. The anterior outgrowth also develops in the human embryo, but it very soon disappears entirely.

The posterior commissure is formed by fibres which invade the lower wall of the pineal recess from both sides.

The nucleus habenulæ, which is the most important constituent of the trigonum habenulæ, is formed from the lateral wall of the diencephalon and is at first in close relationship with the geniculate bodies, from which it becomes separated by the backward growth of the thalamus.

The roof-plate of the diencephalon, in front of the pineal body, remains thin and epithelial in character, and is subsequently invaginated by the choroid plexuses of the third ventricle. Prior to the development of the corpus callosum and the fornix it lies at the bottom of the longitudinal fissure, which separates the two cerebral hemispheres from each other.

The floor of the diencephalon takes part in the formation of the *hypothalamus*, including the corpora mamillaria, the tuber cinereum and the infundibulum of the hypophysis cerebri.

The corpora mamillaria arise as a single thickening which becomes divided by a median furrow during the third month. Anterior to the corpora mamillaria the tuber cinereum develops as a cellular proliferation which extends forwards as far as the infundibulum.

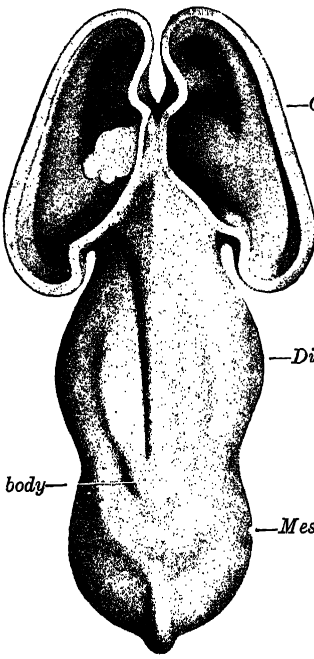
In front of the tuber cinereum the floor of the diencephalon gives origin to

a wide-mouthed diverticulum, which grows downwards and comes into relationship with the posterior aspect of Rathke's pouch (p. 166). These two ectodermal diverticula, the one derived from the floor of the neural tube and the other from the roof of the stomodœum, together form the *hypophysis cerebri* (fig. 209, p. 166). The upper end of the neural outgrowth persists as the infundibular recess of the third ventricle.

The optic vesicles, which are described with the development of the eye (p. 125), are derived from the lateral wall of the prosencephalon before the telencephalon can be identified. They are usually regarded as derivatives of the diencephalon, and the optic chiasma indicates the boundary between the di- and the telencephalon.

The *telencephalon* consists of a median portion and two lateral diverticula. The median portion forms the anterior part of the cavity of the third ventricle, and is closed below and in front by the *lamina terminalis*. The lateral diverticula consist of outward pouchings of the lateral walls of the prosencephalon, which may correspond to the alar laminæ, although this is uncertain; the cavities represent the future lateral ventricles, and their walls the nervous matter of the cerebral hemispheres. The roof-plate of the median part of the telencephalon remains thin, and is continuous behind with the roof-plate of the diencephalon. In the floor-plate and the lateral walls of the prosencephalon ventral to the primitive interventricular foramen the anterior part of the *hypothalamus* is developed; this includes the optic chiasma and the optic recess. The optic chiasma is formed by the meeting and partial decussation of the optic nerves which subsequently grow backwards as the optic tracts and end in the diencephalon and mid-brain.

FIG. 149.—Dorsal view of the prosencephalon of a human embryo 13·6 mm. long (after His). Observe that the cerebral hemispheres are just beginning to overlap the diencephalon.



The cerebral hemispheres arise as diverticula of the lateral walls of the telencephalon, with which they remain in continuity around the upper, anterior and lower margins of the large, interventricular foramen. At the posterior margin of the foramen the wall of the hemisphere is continuous with the anterior part of the lateral wall of the diencephalon (fig. 147); as growth proceeds the hemisphere enlarges forwards, upwards and backwards and acquires an oval outline, with medial and superolateral walls and a floor. As a result the medial surfaces are separated from each other by a cleft which subsequently becomes the longitudinal fissure. At this stage the floor of the cleft is formed by the epithelial roof-plate of the telencephalon, which is directly continuous posteriorly with the epithelial roof-plate of the diencephalon (fig. 151).

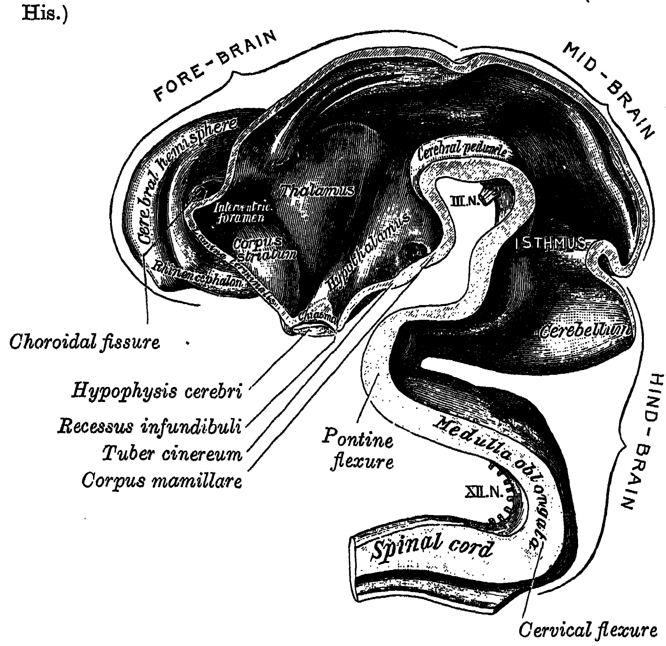
The anterior pole of the oval hemisphere becomes the frontal pole, but, as the hemisphere enlarges, its original posterior pole is apparently carried downwards and forwards to form the temporal pole and a new posterior pole becomes defined, which will persist as the occipital pole of the adult brain. The enormous expansion of the cerebral hemispheres is characteristic of the mammalia and especially of man, and in their subsequent growth they hide, successively, the diencephalon, the mesencephalon and the cerebellum.

About the fourth week a longitudinal groove appears in the anteromedial

part of the floor of the ventricle. This groove deepens and forms a hollow diverticulum connected to the hemisphere by a short stalk. The diverticulum becomes connected on its ventral or inferior surface to a ganglionic mass, the cells of which receive the afferent axons of the sensory cells of the olfactory plate. As the head increases in size the diverticulum grows forwards and, subsequently losing its cavity, becomes converted into the solid olfactory bulb. The forward growth of the bulb is accompanied by the elongation of its stalk, which forms the olfactory tract, and the portion of the floor of the hemisphere to which the tract is attached constitutes the *piriform area.*

The pia mater which covers the epithelial roof of the third ventricle at this stage consists of loosely arranged mesenchyme. In the meshes of this tissue numerous blood-vessels develop, and on each side of the median plane these

Fig. 150.—The brain of a human embryo 13·6 mm. long. Medial surface of right half. The roof of the hind-brain has been removed. (From a model by His.)

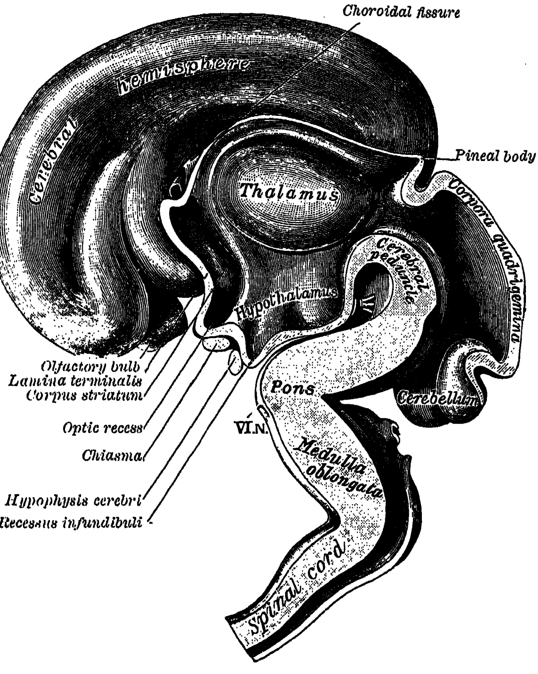


vessels subsequently invaginate the roof of the ventricle to form its *choroid plexuses.* The lower part of the medial wall of the hemisphere, which immediately adjoins the epithelial roof of the interventricular foramen and the anterior extremity of the diencephalon, remains epithelial in character while elsewhere the walls of the hemisphere are thickening to form the pallium. This thin part of the medial wall of the hemisphere is invaginated by vascular tissue, continuous in front with the choroid plexus of the third ventricle and constituting the choroid plexus of the lateral ventricle. This invagination occurs along a line which passes upwards and backwards, parallel with the anterior and upper boundaries of the interventricular foramen, and the curved indentation of the ventricular wall is termed the *choroidal fissure.*

At first growth proceeds more actively in the floor and the adjoining part of the lateral wall of the developing hemisphere, and an elevation is formed which encroaches on the cavity of the lateral ventricle. This elevation is the rudimentary *corpus striatum,* and it extends forwards to the floor of the interventricular foramen where it is separated from the developing anterior end of the thalamus only by a groove. Posteriorly the corpus striatum is, from the beginning, in close relationship to the temporal pole of the hemisphere and, when the occipital pole grows backwards and the general enlargement of the hemisphere carries the temporal pole downwards and forwards, it is continued from the floor of the body of the ventricle into the roof of the inferior horn.

As the hemisphere enlarges the posterior part of its medial surface overlaps and hides the lateral surface of the diencephalon (thalamic part), being separated from it by a narrow cleft occupied by vascular connective tissue. At this stage (end of second month) a transverse section made behind the interventricular foramen passes successively through: (1) the developing thalamus, (2) the narrow cleft just mentioned, (3) the thin medial wall of the hemisphere, and (4) the cavity of the lateral ventricle with the corpus striatum in its floor and lateral wall (fig. 152, A). As the thalamus increases in extent it acquires a superior, in addition to its medial and lateral surfaces, and the lateral part of its superior surface fuses with the thin medial wall of the hemisphere, so that, in the adult, this part of the thalamus is covered with the ependyma of the lateral ventricle immediately below the choroidal fissure (fig. 152, B). As a

FIG. 151.—The brain of a human embryo, about three months old. Medial surface of right half. (From a model by His.)



result the corpus striatum is approximated to the thalamus and separated from it only by a deep groove, which becomes obliterated by increased growth along the line of contact. The lateral aspect of the thalamus is now in continuity with the medial aspect of the corpus striatum, so that a secondary union between the diencephalon and the telencephalon is effected over a wide area, providing a satisfactory and convenient route for the subsequent passage of itinerant (projection) fibres to and from the pallium.

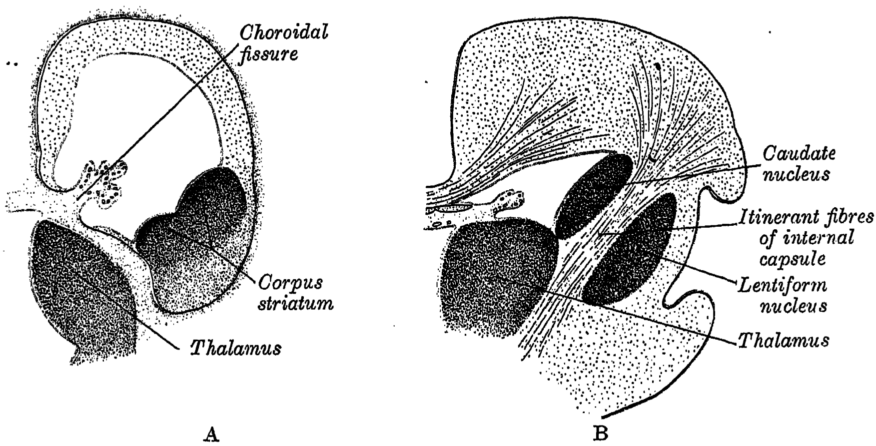
The pallial area which borders the interventricular foramen and lies outside the choroidal fissure constitutes the *archipallium*, and is associated with the reception, interpretation and association of olfactory impressions. It is the first part of the pallium to undergo differentiation, and at first it forms a continuous, almost circular strip on the medial and inferior aspects of the hemisphere, i.e. along the medial fringe of the pallium. Below and in front, where the stalk of the olfactory tract is attached, it constitutes the *piriform area*. The area outside the curve of the choroidal fissure constitutes the *hippocampal formation* (fig. 153).

In this region the cells of the pallium proliferate, and the wall of the hemisphere thickens and produces an elevation which projects into the medial side of the ventricle. This elevation is the *hippocampus*. It appears first on the medial wall of the hemisphere above the area in front of the lamina terminalis

(preterminal area) and gradually extends backwards into the region of the temporal pole where it adjoins the piriform area. The marginal zone in the region of the hippocampus becomes invaded by nerve cells which form the *dentate gyrus*. This structure is practically co-extensive with the hippocampus, and, like it, extends from the preterminal area backwards above the choroidal fissure and follows its curve downwards and forwards towards the temporal pole, where it runs into the piriform area. A shallow surface depression, which has been termed the *hippocampal sulcus*, grooves the medial surface of the hemisphere in the region of the hippocampal formation, but it is not responsible for the elevation which the hippocampus forms in the interior of the ventricle.

The efferent fibres from the cells of the hippocampus collect along its medial edge and run forwards immediately above the choroidal fissure. Anteriorly

FIG. 152.—Diagrams illustrating transverse sections across the developing thalamus and cerebral hemisphere.



In *A* the lateral aspect of the thalamus is separated from the medial aspect of the hemisphere by an interval containing vascular mesenchyme.

In *B* this interval has disappeared; the expanded upper surface of the thalamus is covered by the ependyma of the lateral ventricle; and the approximation of the thalamus and the corpus striatum has provided a pathway for the itinerant (projection) fibres of the internal capsule.

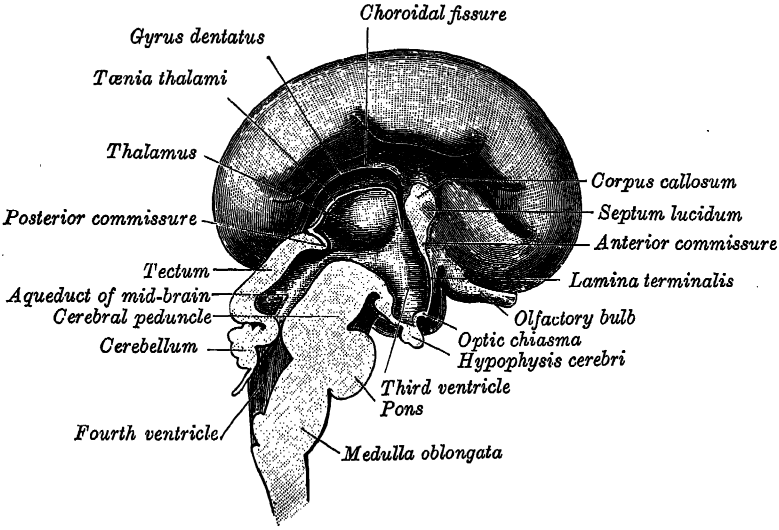
they turn downwards and enter the lateral part of the lamina terminalis in order to gain the hypothalamus, where they terminate in the corpus mamillare. These efferent, hippocampal fibres form the *fimbria* and the *fornix*.

The development of the commissures effects a very profound alteration on the medial wall of the hemisphere. At the time of their appearance the two hemispheres are connected to each other by the median part of the telencephalon. The roof-plate of this area remains epithelial and non-nervous, while its floor becomes invaded by the fibres of the optic nerves. These two routes are not available for the passage of commissural fibres passing from hemisphere to hemisphere across the median plane, and these fibres are therefore compelled to pass through the anterior wall of the interventricular foramen, i.e. the *lamina terminalis*. The first commissures to develop are those associated with the rhinencephalon. Fibres of the olfactory tracts cross in the ventral or lower part of the lamina terminalis and constitute the anterior part of the *anterior commissure*. In addition the two hippocampi become connected to each other by transverse fibres which cross from fornix to fornix in the upper part of the lamina terminalis and give origin to the *hippocampal commissure*.

The neopallial commissures develop later and follow the pathways already established by the commissures of the rhinencephalon. Fibres coming from the tentorial surface of the hemisphere join the anterior commissure and constitute its larger, posterior part. All the other commissural fibres of the neopallium associate themselves closely with the hippocampal commissure and lie on its dorsal surface. These fibres increase enormously in number, and the bundle rapidly outgrows its neighbours to form the corpus callosum (fig. 153).

The first fibres of the corpus callosum lie within the limits of the lamina terminalis, but as the commissure increases in size it extends forwards and upwards and then backwards far beyond those limits. Since the fibres which enter the commissure from the temporal, parietal and occipital regions outnumber those coming from the frontal region, the principal enlargement occurs in a backward direction. As the corpus callosum grows backwards it extends above the choroidal fissure, carrying the hippocampal commissure on its under surface. In this way a new floor is formed for the longitudinal fissure, and additional structures come to lie above the epithelial roof of the third ventricle. In its backward growth the corpus callosum invades the area hitherto occupied

FIG. 153.—The brain of a human embryo, four months old. Medial surface of left half. (Marchand.)



by the upper part of the hippocampal formation, and the corresponding parts of the dentate gyrus (fig. 153) and hippocampus are reduced to mere vestiges, viz. the indusium griseum and the longitudinal striæ.

The lower parts of both the dentate gyrus and the hippocampus persist, for owing to the forward growth of the temporal lobe the brain stem presents an impassable barrier to further growth of the corpus callosum.

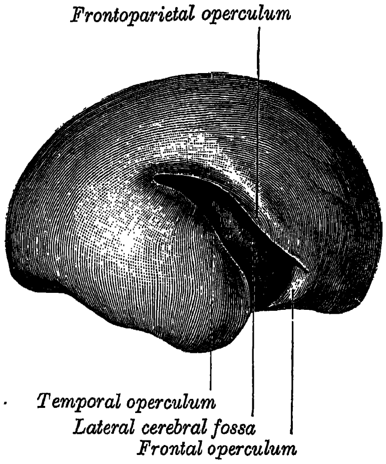
The growth of the neopallium and its enormous expansion is associated with the appearance of the itinerant (projection) fibres during the latter part of the third month. These fibres follow the pathway provided by the apposition of the lateral aspect of the thalamus with the medial aspect of the corpus striatum, and, as they do so, they divide the latter, almost completely, into a lateral part (the lentiform nucleus), and a medial part (the caudate nucleus), these two nuclei remaining unseparated only in their antero-inferior portions.

At the end of the third month the lateral aspect of the cerebral hemisphere shows a slight depression above and in front of the temporal pole. This hollow corresponds to the site of the corpus striatum in the floor and lateral wall of the ventricle, and its presence is due to the more rapid growth of the adjoining pallial areas. This lateral cerebral fossa gradually becomes overlapped and submerged so that the fossa is converted into the lateral cerebral sulcus and its floor becomes the insula (fig. 154). The process, however, is not completed in its most anterior part until after birth.

The growth changes in the temporal lobe which help to submerge the insula produce important changes in the rhinencephalon. The olfactory tract is continuous, on the one hand, with the medial olfactory gyrus, which turns upwards in front of the lamina terminalis, and, on the other hand, with the lateral olfactory gyrus, which is directly continuous with the piriform area. The forward growth of the temporal pole and the general expansion of the neopallium cause the lateral olfactory gyrus to bend laterally, the summit

of the convexity lying at the antero-inferior corner of the developing insula (fig. 155). During the fourth and fifth months the piriform area becomes submerged by the adjoining neopallium, and in the adult only a part of it remains visible on the inferior aspect of the cerebrum.

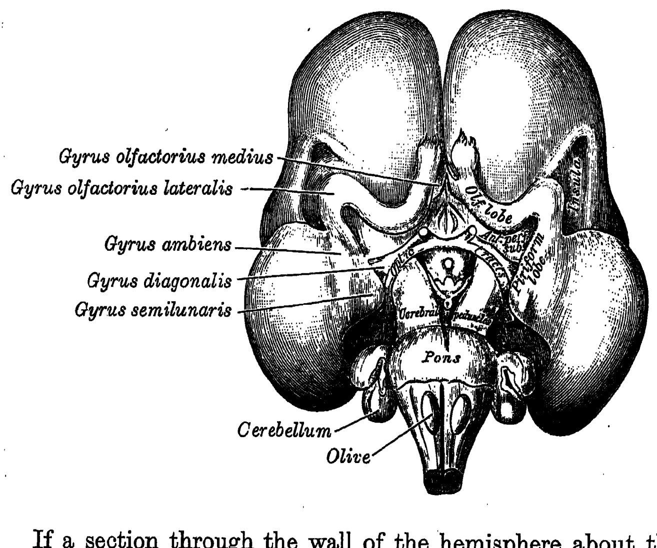
FIG. 154.—The right cerebral hemisphere of a human embryo, about five months old. Lateral surface.



Apart from the shallow hippocampal sulcus and the lateral cerebral fossa the surfaces of the hemisphere remain smooth and uninterrupted until the beginning of the fourth month (fig. 154). The parieto-occipital sulcus appears about that time on the medial aspect of the hemisphere, and its appearance is due to the traction exerted by the splenial fibres of the corpus callosum. At about the same period the postcalcarine sulcus appears as a shallow groove extending forwards from the region of the occipital pole. It is a true infolding of the cortex and forms in the long axis of the striate area, producing at the same time an elevation named the calcar avis on the medial wall of the posterior horn of the ventricle.

During the fifth month the sulcus cinguli appears on the medial aspect of the hemisphere, but it is not until the sixth month that sulci appear on the inferior and superolateral aspects. The central, precentral and postcentral sulci appear each in two parts, upper and lower, which usually coalesce shortly afterwards, although they may remain ununited. The superior and inferior frontal, the intraparietal, occipital, temporal and collateral sulci make their appearance during the same period, and by the end of the seventh month all the important sulci can be recognised.

FIG. 155.—The brain of an embryo at the beginning of the fourth month. Inferior surface. (Kollmann.)



If a section through the wall of the hemisphere about the sixth week be examined microscopically it is seen to consist of a thin marginal layer, an intermediate mantle layer and an inner, thick ependymal layer. It therefore resembles the spinal cord at the same stage. Thereafter, however, neuroblasts from the ependymal and mantle layers migrate into the deep part of the marginal layer and form the cells of the cerebral cortex in that situation. The differentiation of the cortex is described on p. 988.

At birth the volume of the brain is approximately 25 per cent. of its volume in adult life. The greater part of the increase occurs during the first year of life, at the end of which the volume of the brain has increased to 75 per cent. of its adult volume. The growth can be accounted for partly by increase in the size of the nerve-cells in the cerebral blood-vessels, but it is the acquisition of their medullated sheaths by the nerve fibres which is principally responsible for it. The great sensory pathways, visual, auditory and somatic, become medullated first, and later the pyramidal fibres. During the second year and subsequent years growth proceeds much more slowly, and the brain attains its adult size by the seventeenth or eighteenth year. The continued growth is connected with the continued medullation of nerve fibres.

A summary of the parts derived from the cerebral vesicles is given in the following table :—

Rhombencephalon or hind-brain	1. Myelencephalon	Medulla oblongata. Lower part of fourth ventricle.
	2. Metencephalon	Pons. Cerebellum. Intermediate part of fourth ventricle.
	3. Isthmus rhombencephali	Superior medullary velum. Superior cerebellar peduncles. Upper part of fourth ventricle.
Mesencephalon or mid-brain		Cerebral peduncles. Tectum (lamina quadrigemina). Aqueduct.
Prosencephalon or fore-brain	1. Diencephalon	Thalamus. Metathalamus. Epithalamus. Posterior part of hypothalamus. Posterior part of third ventricle.
	2. Telencephalon	Anterior part of third ventricle. Anterior part of hypothalamus. Cerebral hemispheres. Lateral ventricles. Interventricular foramen.

The cranial (cerebral) nerves.—With the exception of the olfactory and optic nerves, which will be considered separately, the cranial nerves are developed in a similar manner to the spinal nerves.

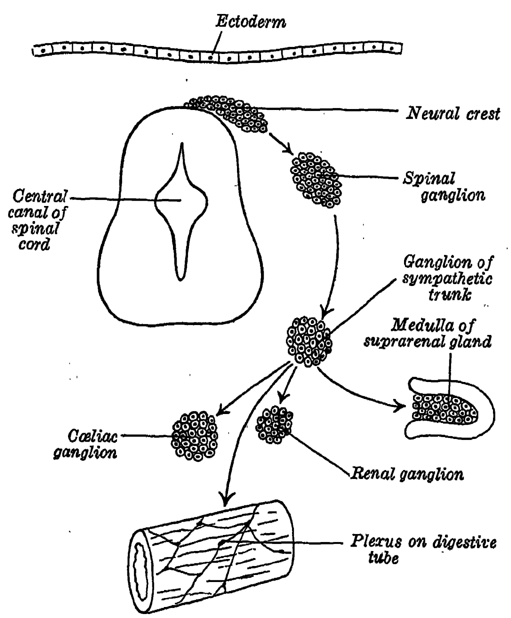
The fibres of the motor cranial nerves are the axons of cells in the basal lamina of the mid- and hind-brains, and pass outwards to their distribution, but whereas the motor fibres of the spinal nerves form one series, those of the cranial nerves form two, according as they are derived from the medial or lateral parts of the basal lamina. The first series comprises the oculomotor, trochlear, abducent and hypoglossal nerves ; the second comprises the accessory nerve, and the motor parts of the trigeminal, facial, glossopharyngeal and vagus nerves, all of which supply the striped muscles derived from the visceral arches.

As the lips of the neural groove fuse with each other in the region of the hind-brain, a *ganglion-crest* is formed which is homologous with the neural crest of the spinal cord. The ganglia of the vagus, glossopharyngeal, auditory (in part), facial and trigeminal nerves are derived from the ganglion-crest, but they migrate ventrally and soon come to lie on the ventrilateral aspect of the hind-brain. It is probable that the crest is not the sole source of origin of the cells in some of these ganglia. Thickened patches of ectoderm (epibranchial placodes) which are developed at the dorsal ends of the branchial clefts probably contribute cells to the facial, glossopharyngeal and vagal ganglia, and the cells of the auditory vesicle are believed to make a substantial contribution to the formation of the ganglia on the auditory nerve. The central processes of the cells of these ganglia form the sensory roots of these nerves and

enter the alar lamina of the hind-brain, while their peripheral processes enter the nerves themselves. The incoming fibres from the facial, glossopharyngeal and vagus nerves collect to form an oval bundle, termed the tractus solitarius (p. 112), on the lateral aspect of the myencephalon. This bundle is the homologue of the oval bundle of the spinal cord.

The **autonomic system.**—The ganglion cells of the *sympathetic system* are derived from the neural crest through the medium of the primitive spinal ganglia. Certain of the cells in the ventral parts of these ganglia migrate towards the sides of the aorta, where they subsequently form the ganglia of the sympathetic trunks. Others migrate still further and eventually form the subsidiary sympathetic ganglia (fig. 156). In the rabbit the original migration is limited to the thoracic and upper lumbar regions. Thereafter the chain grows headwards and tailwards until the whole trunk is laid down. The view has been advanced that the sympathetic ganglion cells are, at least in part, derived from cells which migrate from the basal lamina along the anterior nerve roots. The results of destruction of the neural crest in chick embryos and of excision of the neural crest and portions of the neural tube in frog embryos have been somewhat contradictory in the hands of different investigators. On the whole the balance of the evidence favours the earlier view.

FIG. 156.—Diagram showing the chief derivatives of the neural crest.



The ganglion cells of the cranial part of the *parasympathetic system* are probably derived from the ganglion crest through the medium of the primitive ganglia of the fifth, seventh, ninth and tenth cranial nerves. The ciliary ganglion is formed by cells which migrate from the trigeminal (semilunar) ganglion along the ophthalmic nerve, but it almost certainly is reinforced by cells migrating from the nucleus of the oculomotor nerve. The sphenopalatine ganglion receives contributions from the ganglia of the fifth and seventh nerves; the otic from those of the fifth and ninth; and the submandibular (submaxillary) from those of the fifth and seventh cranial nerves.

The **meninges.**—The dura mater, which is always intimately related to skeletal structures, is mesodermal in origin. The arachnoid mater and the pia mater, however, are more closely related to the brain and the spinal cord, and, although it is customary to regard them as mesodermal in origin, recent experimental work * is strongly suggestive of their derivation from the neural crest ectoderm. Portions of the neural tube transplanted without the adjoining portion of the neural crest develop a covering of dura mater, but no fluid spaces, such as the subarachnoid space, are formed and no choroid plexus develops. If, however, the adjoining part of the neural crest is included in the graft, the transplant develops coverings of arachnoid mater and pia mater and subarachnoid and subdural spaces in addition to an outer covering of dura mater.

The **chromaffin organs.**—The tissue from which the sympathetic ganglia are formed is at first a syncytium of cells termed *sympathochromaffin cells*, but later two varieties of cells—small and large—are differentiated from it; the small cells (sympathoblasts) are transformed into the sympathetic nerve-cells, the large become chromaffin cells, and, separating from the others, accumulate to

* S. C. Harvey and H. S. Burr, *Arch. of Neurology and Psychiatry*, vol. xv., 1926.

form the chromaffin organs. In the trunk of the sympathetic the chromaffin bodies are situated in depressions in the ganglia; the medulla of the suprarenal glands is formed from the chromaffin cells (fig. 156). In connexion with certain, but not all, of the secondary plexuses of the sympathetic system chromaffin organs are found; the largest members of this series are the *aortic bodies*, which lie along the sides of the abdominal aorta between the superior mesenteric and common iliac arteries; to this group belong also the *carotid glomera* (carotid bodies). After birth the aortic bodies and the chromaffin bodies of the sympathetic ganglia degenerate and can no longer be isolated by gross dissection, but chromaffin tissue can be recognised with the microscope in the sites originally occupied by them.

The suprarenal glands.—Each suprarenal gland consists of a cortical portion derived from the cœlomic epithelium and a medullary portion originally composed of sympathochromaffin tissue. The cortical portion is first recognisable about the beginning of the sixth week as a series of buds from the cœlomic cells at the root of the mesentery. Later these buds are separated from the cœlomic epithelium and form a suprarenal ridge projecting into the cœlom between the mesonephros and the root of the mesentery. In the eighth week cells from the neighbouring masses of sympathochromaffin tissue migrate into this cortical portion along the line of its central vein and form the medullary portion of the gland.

The nose.—The development of the nose has already been considered (pp. 92 to 97).

The *olfactory nerves* are developed from the cells of that part of the ectoderm which lines the olfactory pits; these cells undergo proliferation and give rise to what are termed the *olfactory cells* of the nose. The central processes of these cells are usually described as growing into the overlying olfactory bulb and forming the olfactory nerves. It has, however, been shown that the olfactory cells are from the first connected with the brain by a bridge of protoplasm which is never severed, and that the olfactory nerve fibres are developed in this bridge.*

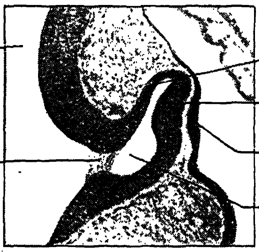
The eyes.—The rudiments of the eyes appear as a pair of hollow diverticula from the lateral aspects of the fore-brain. These diverticula are visible before the closure of the anterior neuropore; after its closure they are known as the *optic vesicles*. They project towards the sides of the head, and the distal part of each expands while the proximal part remains narrow and constitutes the *optic stalk* (figs. 157, 159). A small area of ectoderm overlying the optic vesicle becomes thickened and depressed in its centre. The depression deepens and its edges come together and fuse so as to enclose a hollow vesicle (figs. 157, 158) which soon loses its connexion with the surface ectoderm. This is the *lens-vesicle*, or rudiment of the lens. The outer wall of the optic vesicle increases in thickness and undergoes invagination so that the vesicle is converted into a cup, termed the *optic cup*, consisting of two strata of cells (fig. 158). These two strata are continuous with each other at the cup-margin, which ultimately overlaps the front of the lens and reaches as far forward as the future aperture of the pupil. The invagination is not limited to the outer wall of the vesicle, but involves also its caudal surface and extends in the form of a groove for some distance along the optic stalk, and thus, for a time, a wide gap, termed the *choroidal fissure*, exists in the caudal part of the cup (fig. 159). Through the groove and fissure mesenchyme extends into the optic stalk and cup, carrying the hyaloid artery with it; as growth proceeds, the edges of the fissure become approximated and they close during the seventh week, including the artery in the distal portion of the stalk. Sometimes the choroidal fissure persists, and when this occurs the choroid and iris in the region of the fissure remain undeveloped, giving rise to the condition known as *congenital coloboma* of the choroid or iris.

The retina is developed from the optic cup. The outer stratum of the cup persists as a single layer of cells, which assume a columnar shape, acquire pigment, and form the pigmented layer of the retina, the pigment first appearing

* Consult (*a*) an article on "The Cerebral Cortex in Lepidosiren," by Grafton Elliot Smith, *Anatomischer Anzeiger*, Band 33, p. 513, and (*b*) an article by Frances M. Ballantyne on "The Continuity of the Vertebrate Nervous System," *loc. cit.*

in the cells near the edge of the cup. The cells of the inner stratum proliferate and form a layer of considerable thickness from which the nervous elements and the sustentacular fibres of the retina, together with a portion of the vitreous body, are developed. In the portion of the cup which overlaps the lens the inner stratum is not differentiated into nervous elements, but persists as a

Fig. 157.—Section through the optic vesicle of a mole embryo, 3·5 mm. long.



layer of columnar cells which, together with the corresponding part of the pigmented layer, form the *pars ciliaris* and *pars iridica retinæ*.

The cells of the inner layer of the cup proliferate and form an outer nuclear zone and an inner marginal zone, devoid of nuclei. At 12 mm. the cells of the nuclear zone invade the marginal zone, and at 17 mm. the nervous stratum of the retina consists of inner and outer neuroblastic layers, separated by a narrow fibre layer, which disappears as differentiation proceeds. The inner neuroblastic layer gives origin to the ganglion cells, the amacrine

Fig. 158.—Section through the developing eye of a mole embryo, 6·5 mm. long.

cells and the nuclei of the sustentacular fibres ; the outer neuroblastic layer gives origin to the horizontal cells, the bipolar nuclei and the nuclei of the rods and cones, which first appear in the central part of the retina. By the eighth month all the layers of the retina can be identified.*

The optic stalk is converted into the optic nerve by the obliteration of its cavity and the growth of nerve-fibres into it. Most of these fibres are centripetal, and are the axons of the nerve-cells of the ganglionic layer of the retina, but a few are centrifugal and are derived from nerve-cells in the brain. The fibres of the optic nerve receive their medullary sheaths about the tenth week after birth. The optic chiasma is formed by the meeting and partial decussation of the fibres of the two optic nerves, and it marks the junction of the telencephalon with the diencephalon in the floor of the third ventricle. Behind the chiasma the fibres are continued backwards as the optic tracts to the lateral geniculate bodies.

* Ida C. Mann, *Journal of Anatomy*, July, 1927.

The lens is developed from the lens-vesicle, which recedes within the margin of the cup, and becomes separated from the overlying ectoderm by mesenchyme. The cells forming the posterior wall of the vesicle lengthen and are converted into the lens-fibres, which grow into and fill the cavity of the vesicle (fig. 161). The cells forming the anterior wall retain their cellular character, and form

Fig. 159.—The optic cup and the choroidal fissure of a human embryo, about five weeks old. Ventral aspect. (Kollmann.)

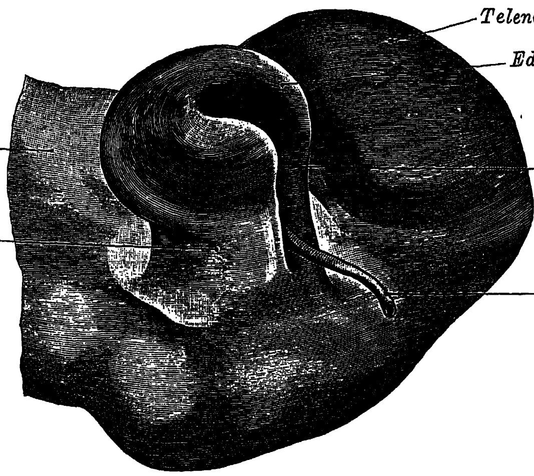
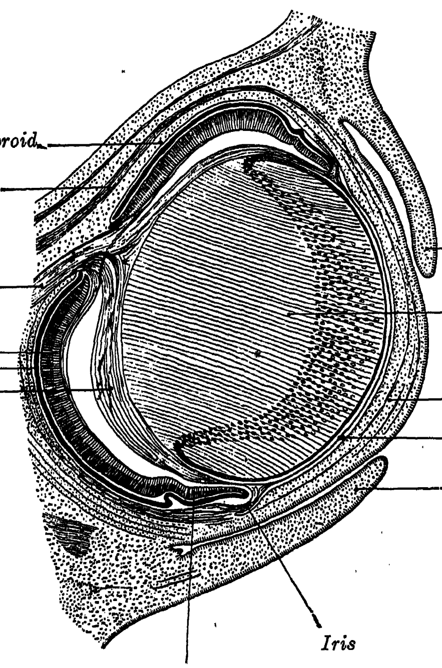


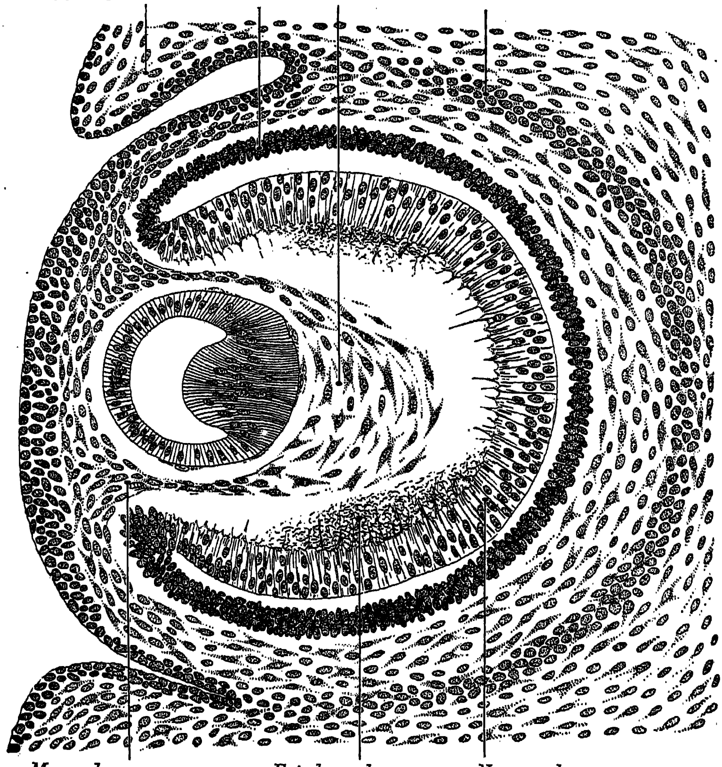
Fig. 160.—A section through the eye of a rabbit embryo, about eighteen days old. ×30. (Kölliker.)



the epithelium on the anterior surface of the fully developed lens; at the equator of the lens the gradual transition of the cells into lens-fibres can be seen. By the second month the lens is invested by a vascular mesenchymal capsule termed the *capsula vasculosa lentis*, the ventral part of which, covering the lens, is named the *pupillary membrane*; the blood-vessels supplying the dorsal part of this capsule are derived from the hyaloid artery; those for the

ventral part from the anterior ciliary arteries. By the sixth month all the vessels of the capsule are atrophied except the hyaloid artery, which becomes occluded during the eighth month of intra-uterine life. Prior to this, during the fourth month, the hyaloid artery gives off retinal branches, and its proximal part persists in the adult as the central artery of the retina. The hyaloid canal, which gives passage to the artery through the vitreous, persists after the vessel has become occluded. In the newly-born child it extends more or less horizontally from the optic disc (papilla) to the posterior aspect of the lens but, when the adult eye is examined with the slit-lamp, it can be seen to follow a

FIG. 161.—A sagittal section through the eye of a human embryo, about six weeks old. (Kollmann.)



wavy, curved course, sagging downwards as it passes forwards to the lens.* With the loss of its blood-vessels the capsula vasculosa lentis disappears, but sometimes the pupillary membrane persists at birth, giving rise to the condition termed *congenital atresia of the pupil.*

The vitreous body is developed between the lens and the optic cup. The lens-rudiment and the optic vesicle are at first in contact with each other, but after the closure of the lens-vesicle and the formation of the optic cup the former is withdrawn from the retinal layer of the cup; the two, however, remain connected by a network of delicate protoplasmic processes. This network, derived partly from the cells of the lens and partly from those of the retinal layer of the cup, constitutes the primitive vitreous body (fig. 161). At first these protoplasmic processes spring from the whole of the retinal layer of the cup, but later are limited to the ciliary region, where by a process of condensation they appear to form the zonula ciliaris. The mesenchyme which enters the cup through the choroidal

* Ida C. Mann, *Journal of Anatomy,* vol. lxii.

fissure and around the equator of the lens becomes intimately united with this reticular tissue, and contributes to the formation of the vitreous body, which is therefore derived partly from the ectoderm and partly from the mesoderm.

The aqueous chamber of the eye appears as a cleft in that part of the mesenchyme which intervenes between the lens and the ectoderm. The layer of mesenchyme ventral to the cleft forms the substantia propria of the cornea, that dorsal to the cleft the mesenchymal stroma of the iris and the pupillary membrane.

The sclera and choroid are derived from the mesenchyme surrounding the optic cup, and the anterior part of the choroid is modified to form the ciliary body and ciliary processes. The fibres of the ciliaris muscle are derived from the mesoderm, but those of the sphincter and dilatator pupillæ are of ectodermal origin, being developed from the cells of the pupillary part of the optic cup.

The eyelids are formed as small cutaneous folds (fig. 161). About the middle of the third month their edges come together and unite over the cornea; they remain united until about the end of the sixth month.

The epithelium of the alveoli and ducts of the lacrimal gland arise as a series of tubular buds from the ectoderm of the superior conjunctival fornix; these buds are arranged in two groups, one forming the gland proper, and the other its palpebral process. The lacrimal sac and nasolacrimal duct result from a thickening of the ectoderm in the *naso-optic furrow* between the lateral nasal and maxillary processes (p. 93). This thickening forms a solid cord of cells which sinks into the mesenchyme; during the third month the central cells of the cord break down, and a lumen—the nasolacrimal duct—is established. The lacrimal canaliculi arise as buds from the upper part of the cord of cells and secondarily establish openings (puncta lacrimalia) on the margins of the lids; the inferior canaliculus cuts off a small part of the lower eyelid to form the caruncula lacrimalis (Ask). The epithelium of the cornea and conjunctiva is of ectodermal origin, as are also the eyelashes and the lining cells of the tarsal and other glands which open on the margins of the eyelids.

The ears.—The rudiments of the internal ears appear shortly after those of the eyes, as two patches of thickened, surface ectoderm, termed the *auditory plates*, which are situated in the region of the hind-brain. Each auditory plate is invaginated and converted into an *auditory pit* (fig. 162). The mouth of the pit is then closed, and a vesicle, termed the *auditory* (*otic*) *vesicle* or *otocyst,* is formed (fig. 163); from it the epithelial lining of the membranous labyrinth is derived. The vesicle assumes a flask-shape, and the neck of the flask is obliterated (fig. 164). From the vesicle certain diverticula are given off which form the various parts of the membranous labyrinth. The first to appear springs from the middle part and forms the ductus and saccus endolymphaticus. A second, from the ventral end, elongates, and forms the coiled tube of the cochlear duct, the proximal or vestibular extremity of which is subsequently constricted to form the ductus reuniens. Before the rudiment of the cochlea can be identified, three diverticula appear as disc-like evaginations from the dorsal part of the vesicle; the central parts of the walls of the discs coalesce and disappear, while the peripheral portions of the discs persist to form the semicircular ducts; the superior duct is the first, and the lateral the last, to be completed (fig. 165). The central part of the vesicle represents the membranous vestibule, and is subdivided by a constriction into a smaller, ventral part termed the saccule, and a larger, dorsal part termed the utricle (fig. 166). This subdivision is effected by a fold which extends deeply into the proximal part of the ductus endolymphaticus, with the result that the utricle and saccule ultimately communicate with each other by means of a Y-shaped canal. The saccule opens into the cochlear duct, through the canalis reuniens; the semicircular ducts communicate with the utricle.

The mesenchyme surrounding the various parts of the epithelial labyrinth is converted into a cartilaginous ear-capsule, and this is finally ossified to form the bony labyrinth of the internal ear. For a time the cartilaginous ear capsule is incomplete, and the cochlear, vestibular, and facial ganglia are situated in the gap between its canalicular and cochlear parts. These ganglia are soon covered by an outgrowth of cartilage and at the same time the facial nerve is bridged by a growth of cartilage from the cochlear to the canalicular parts of the capsule. In the embryonic connective tissue between the cartilaginous capsule

and the epithelial wall of the labyrinth the perilymphatic spaces are developed. Streeter * states that the rudiment of the *periotic cistern* or vestibular perilymphatic space, can be seen in an embryo of from 30 to 40 mm. in length, in the reticulum between the saccule

Fig. 162.—A section through the hind-brain and auditory pits of a human embryo, about twenty-four days old. (Kollmann.)

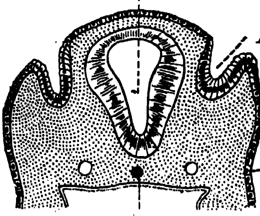
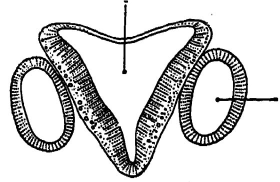


Fig. 163.—A section through the hind-brain and auditory vesicles of an embryo more advanced than that of fig. 162. (After His.)



and the fenestra vestibuli. The scala tympani is next developed, and begins opposite the fenestra cochleæ; the scala vestibuli is the last to appear. The two scalæ gradually extend along each side of the ductus cochlearis, and when they reach the tip of the ductus an opening which represents the helicotrema is developed between them. The modiolus and the osseous spiral lamina of the cochlea are not preformed in cartilage but are ossified directly from connective tissue.

Fig. 164.—The left auditory vesicle of a human embryo, about 6 mm. long. Lateral aspect. (W. His, jun.)

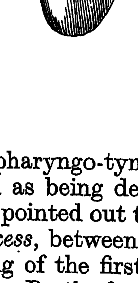
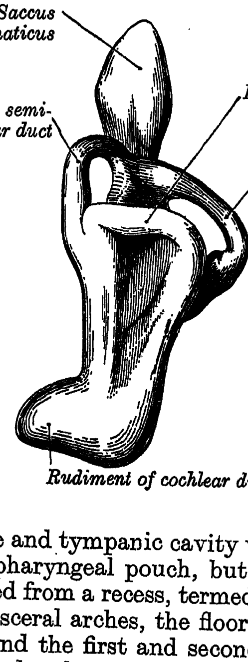


Fig. 165.—The left auditory vesicle of a human embryo, about 15 mm. long. Lateral aspect. (W. His, jun.)



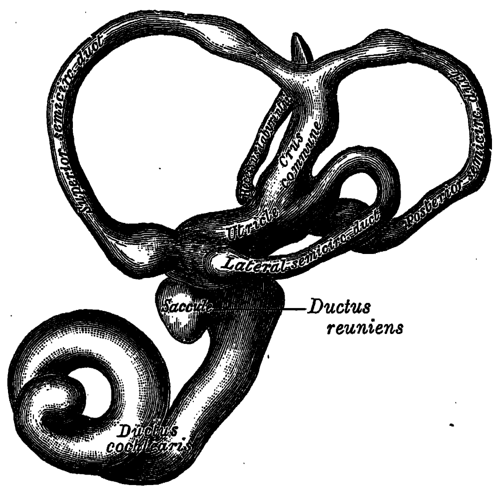
The pharyngo-tympanic (auditory) tube and tympanic cavity were formerly regarded as being derived from the first pharyngeal pouch, but Frazer † has recently pointed out they they are developed from a recess, termed the *tubotympanic recess*, between the first and third visceral arches, the floor of the recess consisting of the first and second arches and the first and second pharyngeal pouches. By the forward growth of the third arch the inner part of the recess is narrowed to form the tubal region, and the inner part of the second arch is excluded from this portion of the floor. The outer part of the recess is subsequently developed into the tympanic cavity, and the floor of this part forms the lateral wall of the tympanic cavity up to about the level of the chorda tympani nerve. From this it will be seen that the lateral wall of the tympanic cavity

* George L. Streeter, *American Journal of Anatomy*, vol. xxi.

† J. Ernest Frazer, *Journal of Anatomy and Physiology*, vol. xlviii.

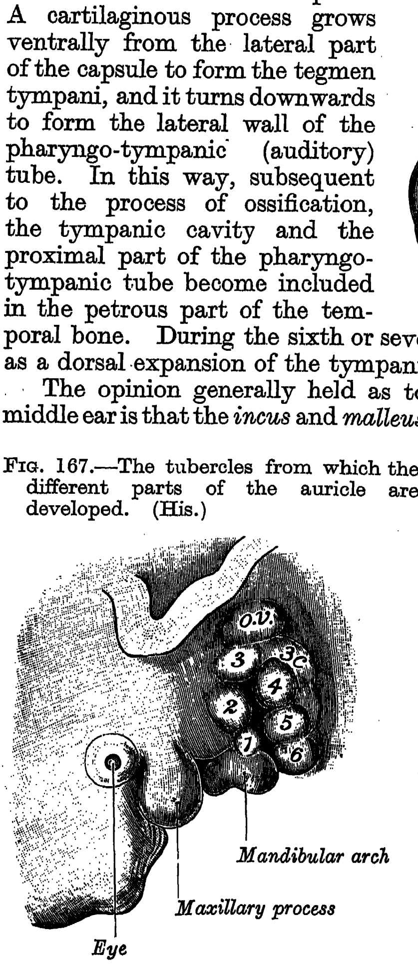
"has both first and second arch elements in it, the share taken by the first arch being limited to the part in front of the handle of the malleus. The area of the second arch includes the outer wall behind this, and turns on to the back wall to take in the tympanohyal region." The tubotympanic recess is placed at first on the infero-lateral aspect of the cartilaginous auditory capsule, but as the latter enlarges the relations become altered and the tympanic cavity comes to lie antero-lateral to the capsule. A cartilaginous process grows ventrally from the lateral part of the capsule to form the tegmen tympani, and it turns downwards to form the lateral wall of the pharyngo-tympanic (auditory) tube. In this way, subsequent to the process of ossification, the tympanic cavity and the proximal part of the pharyngo-tympanic tube become included in the petrous part of the temporal bone. During the sixth or seventh month the tympanic antrum appears as a dorsal expansion of the tympanic cavity.

Fig. 166.—The left membranous labyrinth of a human embryo, 30 mm. long. (From a model by W. His, jun.)



The opinion generally held as to the development of the ossicles of the middle ear is that the *incus* and *malleus* are derived from the dorsal end of the mandibular (Meckel's) cartilage (fig. 131), the incus representing the quadrate bone of birds and reptiles. The *stapes* is developed from the dorsal end of the cartilage of the second or hyoid arch, and first appears as a ring (annulus stapedis) encircling the small stapedial artery, which subsequently atrophies. At first the ossicles are imbedded in the mesenchymal roof of the tympanic cavity, and their extraneous origin is indicated in the adult by the covering which they receive from the mucous lining of the cavity.

Fig. 167.—The tubercles from which the different parts of the auricle are developed. (His.)



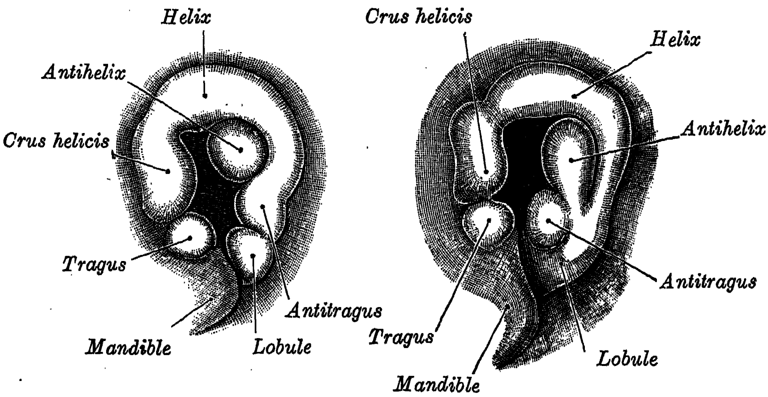
1, 2. Tubercles on mandibular arch. 3. Tubercle above groove. 3, *c*. Prolongation of 3 downwards. 4, 5, 6. Tubercles on hyoid arch. *o.v.* Auditory vesicle.

The external auditory meatus is developed from the dorsal end of the hyomandibular or first visceral cleft. The ventral part of this groove extends inwards as a funnel-shaped tube (primary meatus) from which the cartilaginous portion and a small part of the roof of the osseous portion of the meatus are developed. From the funnel-shaped tube a solid epidermal plug extends inwards along the floor of the tubotympanic recess; by the breaking down of the central cells of this plug the inner part of the meatus (secondary meatus) is produced, while the deepest cells of the ectodermal plug form the epidermal stratum of the tympanic membrane. The fibrous stratum of the tympanic membrane is formed from the mesenchyme which extends between the meatal plate and the entoderm of the floor of the tubotympanic recess.

The auricle is developed by the gradual differentiation of six tubercles (fig. 167) which appear around the margin of the hyo-mandibular cleft. Three

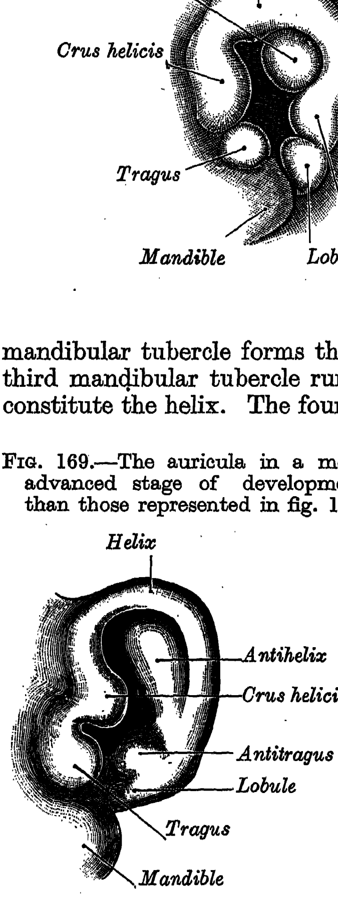
tubercles appear on the caudal edge of the mandibular arch near its dorsal end and three similar tubercles appear on the cephalic edge of the opposed part of the hyoid arch. A short ridge-like elevation, which is termed the *auricular fold,* appears dorsal and caudal to the hyoid tubercles. The first

FIG. 168.—The left auricles of human embryos, about 13·6 and 15 mm. long, respectively. (After His.)



mandibular tubercle forms the tragus, and the second the crus helicis. The third mandibular tubercle runs into the auricular fold, and the two together constitute the helix. The fourth (hyoid) tubercle forms the antihelix, the fifth the antitragus and the sixth the lobule.* Some observers maintain that the fourth and fifth tubercles fuse to form the antihelix, that the sixth becomes the antitragus, and that the lobule develops later as an independent formation. The rudiment of the auditory nerve appears in the fourth week as the *auditory ganglion,* which lies between the auditory vesicle and the wall of the hind-brain. At first it is fused with the ganglion of the facial nerve (acousticofacial ganglion) but later the two separate. The cells of the ganglion are mainly derived from those of the neural crest, but probably some come from the ectoderm of the auditory vesicle. The auditory ganglion divides into a vestibular and a cochlear part, each of which is associated with the corresponding division of the eighth nerve. The cells of these ganglia retain their bipolar shape, each sending a proximal fibre into the brain, and a peripheral fibre to the internal ear.

FIG. 169.—The auricula in a more advanced stage of development than those represented in fig. 171.



THE DEVELOPMENT OF THE VASCULAR SYSTEM

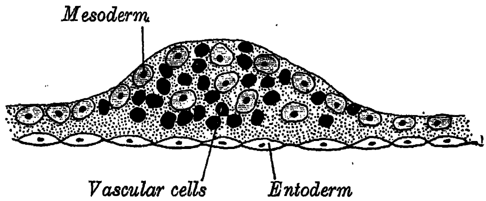
The blood-corpuscles and the blood-vessels are derived from *angioblastic tissue,* which differentiates from the mesoderm in three regions, viz.: (*a*) on the surface of the yolk-sac, (*b*) in the body-stalk, and (*c*) in the chorion.† On

* F. Wood-Jones and Wen I-Chuan believe that the whole of the auricle is developed from hyoid elements, with the exception of the tragus, which is derived from the mandibular arch.—*Journal of Anatomy,* vol. lxviii. 1934.

† J. L. Bremer, " On the Earliest Blood-vessels in Man," *Anatomical Record,* vol. viii. Feb. 1914; Donald McIntyre, " The Development of the Vascular System in the Human Embryo prior to the Establishment of the Heart," *Trans. Roy. Soc. Edin.* vol. lv. 1926; A. T. Hertig, " Angiogenesis in the Early Human Chorion," *Contributions to Embryology,* vol. xxv. 1935.

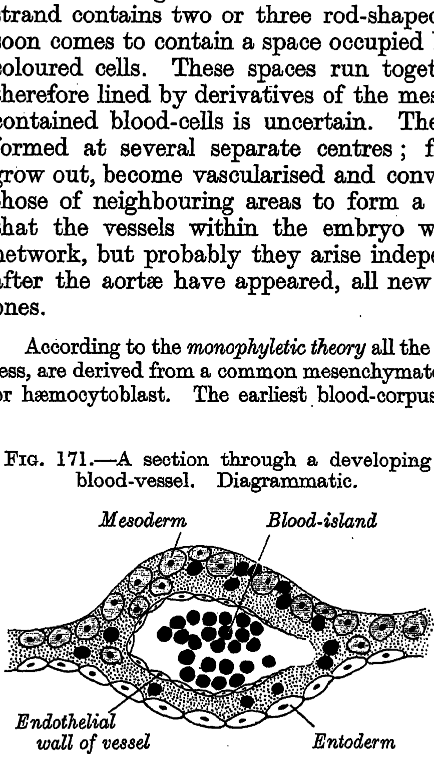
the surface of the yolk-sac and in the body-stalk small, more or less spherical, groups of cells are found early in the third week. They are termed *blood-islands*. The stages of the transformation of blood-islands into blood-containing vessels have not yet been demonstrated in detail, but it is generally believed that the peripheral cells of the islands become flattened and form the vascular endothelium, while the central cells become converted into blood-corpuscles. Later these small blood-containing spaces become continuous with one another to form a network of small vessels. In the chorionic end of the body-stalk and in the mesenchyme lining the chorion typical blood-islands are not found, but the cells of the mesenchyme, give rise to solid strands of angioblast. Each strand contains two or three rod-shaped nuclei arranged in a single row and soon comes to contain a space occupied by one or more nucleated hæmoglobin-coloured cells. These spaces run together to form blood-vessels, which are therefore lined by derivatives of the mesenchyme: the precise source of their contained blood-cells is uncertain. The earliest blood-vessels, therefore, are formed at several separate centres; from the walls of these vessels buds grow out, become vascularised and converted into new vessels, and join with those of neighbouring areas to form a close meshwork. His was of opinion that the vessels within the embryo were developed as extensions of this network, but probably they arise independently. Most observers agree that, after the aortæ have appeared, all new vessels are derived from pre-existing ones.

FIG. 170.—A section through the vascular area to show the differentiation of the primitive vascular cells. Diagrammatic.



According to the *monophyletic theory* all the corpuscles of the blood, both red and colourless, are derived from a common mesenchymatous ancestor, the primitive mesamœboid cell or hæmocytoblast. The earliest blood-corpuscles are thus all nucleated; they are also capable of subdivision and of executing amœboid movements. Some mesamœboids acquire colouring matter (hæmoglobin); their nuclei disintegrate and are extruded, and the non-nucleated red corpuscles or erythrocytes result. Other mesamœboids retain their nuclei; some remain in the blood as the leucocytes; others wander out into the tissues, particularly into the liver, the lymphoid tissues, and the marrow of the bones, where they form specialised collections from which the corpuscles of the blood are regenerated. The different varieties of leucocytes are described on p. 29.

FIG. 171.—A section through a developing blood-vessel. Diagrammatic.



On the other hand, according to the *polyphyletic theory*, which is upheld by Sabin and her school, the angioblast gives origin to red blood-corpuscles and to clasmatocytes, but all the other varieties of leucocytes are derived from a primitive basiphilic ancestor, which is also mesodermal in origin.

The development of the red blood-corpuscles is carried through in three stages. (1) *Erythroblasts* are derived from the primitive mesamœboid and endothelial cells. They are frequently termed *megaloblasts*, and they are the *ichthyoid blood cells* (of Minot), so called because of their resemblance to the typical red blood-corpuscles of fishes. These cells are large in size; they are nucleated and contain hæmoglobin in their cytoplasm. They predominate in the earlier weeks of development, but are not found in normal blood after the third month. (2) The *normoblasts*, which first appear during the second month, closely resemble the red blood-corpuscles of reptiles and were termed *sauroid blood cells* by Minot. Smaller than the erythroblasts the normoblasts have small, deeply staining, spherical nuclei, and their cytoplasm contains an increased amount of hæmoglobin. They are occasionally found in normal blood at birth. (3) The *erythrocytes*, or *blood plastids* (of Minot) are non-nucleated, spherical cells which become converted into typical red blood-

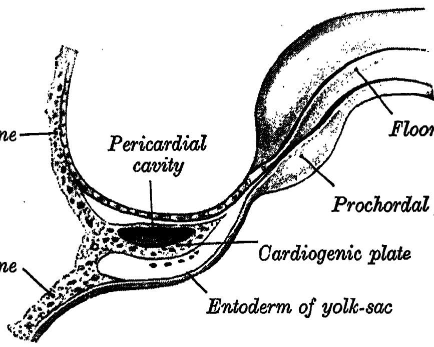
corpuscles. They represent normoblasts which have lost their nuclei, whether by extrusion or by absorption is still somewhat doubtful.

THE DEVELOPMENT OF THE HEART*

The human heart, like the hearts of all vertebrates, is formed by the fusion of two symmetrically developing tubes (p. 82), but the fusion is gradual, commencing at the bulbar, or arterial, end and extending caudally.

The pericardial cavity can be identified before the head-fold is formed or while it is in process of formation, and the heart is then represented only by groups of angioblasts which lie between the pericardium and the entoderm of the yolk-sac (fig. 172). The ventral (or yolk-sac) wall of the pericardium, *which*

Fig. 172.—Median section through the cephalic end of an early human embryo to show the position of the pericardium before the formation of the head-fold. A few scattered angioblasts are seen between the cardiogenic plate and the yolk-sac; they will ultimately form the endothelial heart tubes. (After Carl L. Davis.)



is destined to form both the epicardium and the myocardium, is thicker than the dorsal wall and is termed the *cardiogenic plate*. When the head-fold is formed, the cardiogenic plate becomes the dorsal wall of the pericardium and lies ventral to the fore-gut. While this reversal of the pericardium is taking place (figs. 173 and 174), the angioblastic tissue related to the cardiogenic plate gives rise to two paramedian endothelial tubes which subsequently fuse to form a tubular heart. Caudally each tube receives the cranial end of the corresponding vitelline vein, which lies in the floor of the pericardium in the mesoderm of the septum transversum (p. 72). Ventrally the endothelial heart tubes invaginate the cardiogenic plate into the pericardial cavity (fig. 175).

The dorsal aortæ arise *in situ* as paired endothelial vessels. They extend caudally into the body-stalk, where they establish continuity with the umbilical arteries, which precede them in time of appearance. At their cephalic ends the dorsal aortæ curve ventrally round the sides of the fore-gut to reach the pericardium to become continuous with the cephalic ends of the endothelial heart tubes, thus forming the first pair of aortic arches † (fig. 189).

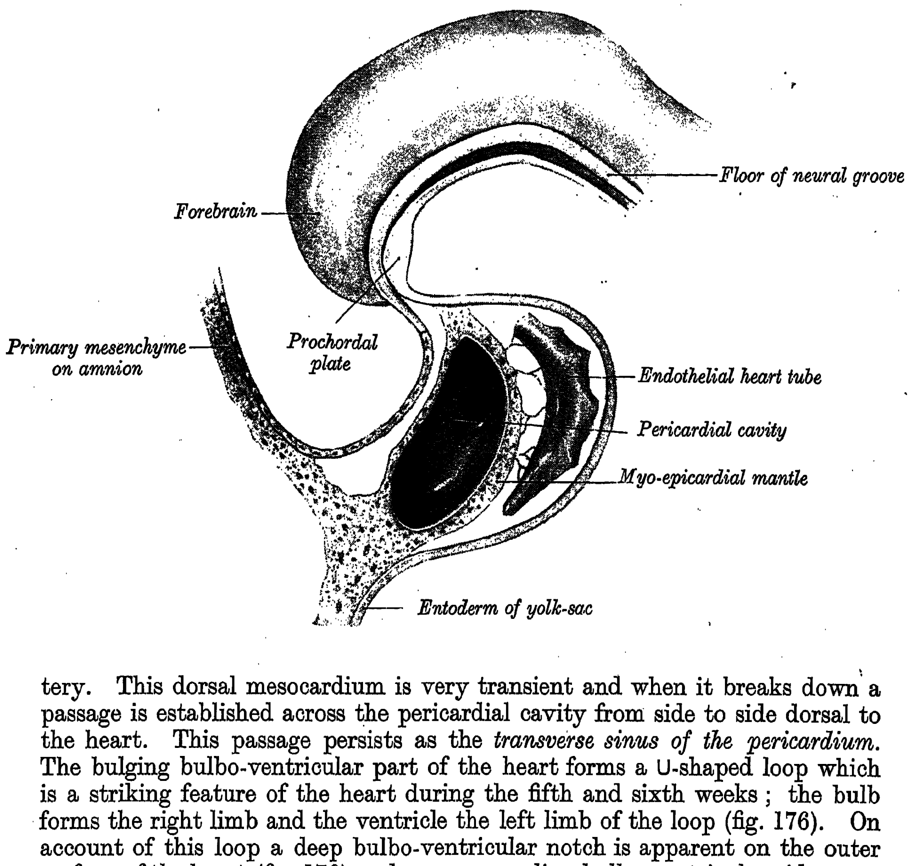
Except at its caudal end the tubular endothelial heart is separated from the cardiogenic plate—which may henceforth be termed the *myo-epicardial mantle*—by an interval occupied by a formless jelly-like substance (fig. 175). At first the pericardium is wide in proportion to its length, but as the heart tube grows the pericardium for a time lengthens proportionately. Grooves appear on the surfaces of the heart which indicate the subdivision of the tube into its primitive chambers. The most cranially situated of these grooves marks off

* See A. Girgis, *Proceedings of Zoological Society of London*, 1930 and 1933; Carl L. Davis, *Contributions to Embryology*, vol. xix. 1927; D. Waterston, *Trans. Roy. Soc. Edinburgh*, vol. lii. 1918; and J. Tandler, *Keibel and Mall's Manual of Embryology*, 1912.

† In lower vertebrates the heart and aortæ are laid down before the formation of the head-fold and the arteries communicate with the caudal end of the heart. When the head-fold forms, the ends of the heart are reversed and the cephalic ends of the dorsal aortæ are curved forwards round the sides of the fore-gut to form the first aortic arches.

the *bulbus cordis*, which is continuous with the first pair of aortic arches, from the *ventricle*. A second groove, which later becomes a localised constriction, separates the ventricle from a common *sinu-atrial chamber* and indicates the position of the *atrial canal*. At the same time the heart-tube is enlarging and the bulbo-ventricular part, which is most affected, bulges ventrally and caudally. The dorsilateral recesses of the pericardium deepen and approach one another (fig. 175) and fuse, completing the myo-epicardial covering of the heart and converting its hitherto broad dorsal attachment into a dorsal mesen-

FIG. 173.—Median section through the cephalic end of a young human embryo, showing the head-fold in process of formation and its effect on the position of the pericardium. Compare with figs. 172 and 174. (After Carl L. Davis.)



tery. This dorsal mesocardium is very transient and when it breaks down a passage is established across the pericardial cavity from side to side dorsal to the heart. This passage persists as the *transverse sinus of the pericardium.* The bulging bulbo-ventricular part of the heart forms a U-shaped loop which is a striking feature of the heart during the fifth and sixth weeks; the bulb forms the right limb and the ventricle the left limb of the loop (fig. 176). On account of this loop a deep bulbo-ventricular notch is apparent on the outer surface of the heart (fig. 176) and a corresponding bulbo-ventricular ridge projects into the interior (fig. 186).

The bulbo-ventricular loop occupies the ventral part of the pericardial cavity, while the common sinu-atrial chamber occupies its dorsal part. The atrial canal, consequent on the formation of the loop, lies to the left of the median plane, so that at this stage, it is the left part of the sinu-atrial chamber which communicates with the ventricle. During the subsequent growth changes the canal gradually moves into the median plane of the heart.

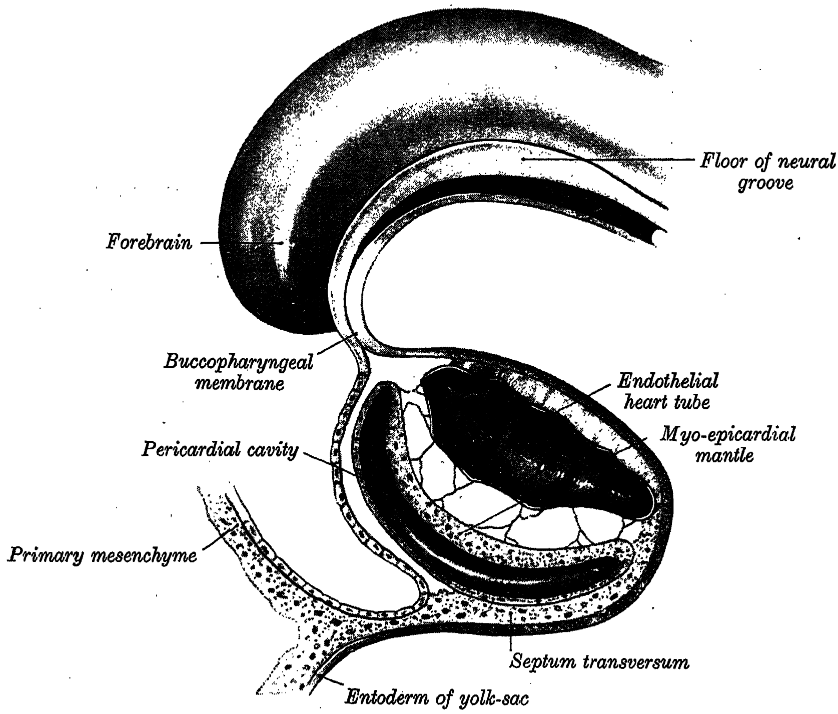
While these changes are in progress the connexion between the bulbus cordis and the first pair of aortic arches lengthens to form the *truncus arteriosus*, and the cranial end of this vessel becomes connected to the dorsal aortæ by the remaining (five) pairs of aortic arches. By this time the venous drainage of the body wall has been established. On each side an *anterior cardinal vein*, from the headward end of the embryo, unites with a *posterior cardinal vein* from the tail end, to form the *duct of Cuvier*, and this vessel opens close to the umbilical and vitelline veins into the dorsi-caudal part of the common sinu-atrial chamber.

The separation of the *sinus venosus* from the *atrium* completes the definition

of the primitive chambers of the heart. This is effected by the appearance of a crescentic fold which cuts off the dorsi-caudal part of the sinu-atrial chamber to form the sinus venosus. The fold is much deeper on the left side, so that the left horn of the sinus venosus is defined first, and opens into that part of the common sinu-atrial chamber which later becomes the right horn (fig. 178), As the crescentic fold deepens, the right horn becomes demarcated from the right half of the common atrium and its connexion with it—which is widely open in fig. 178—becomes relatively smaller. The right and left parts of the atrium enlarge and bulge forwards at the sides of the bulb (fig. 181).

The embryo has now attained a length of 3 mm. It possesses no somites and has entered on the fifth week of development. From this stage onwards it

FIG. 174.—Median section through the cephalic end of a young human embryo, after completion of the head-fold and reversal of the pericardium. Compare with figs. 172 and 173. (After Carl L. Davis.)

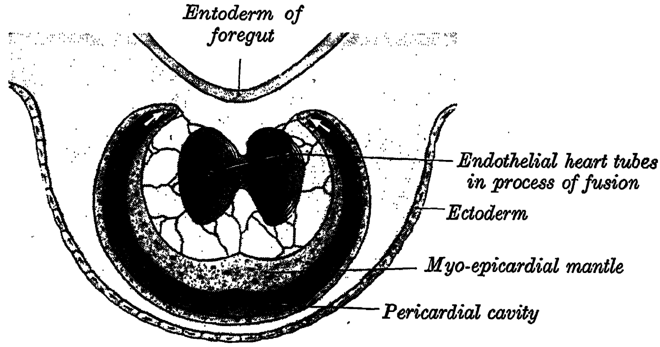


is more convenient to deal with the history of the individual chambers than with the development of the heart as a whole.

The sinus venosus.—The sinus venosus is situated in the septum transversum dorsi-caudal to the common atrium, and presents a crescentic shape (fig. 179). Its right horn increases rapidly in size at the expense of the left horn, owing to the changes brought about in the originally symmetrical arrangement of the umbilical and vitelline veins by the development of the liver (p. 154). As a result of these changes the vitello-umbilical blood-flow enters the right horn through a wide but short vessel, termed the *vena hepatis communis*, which is destined to form the cephalic end of the inferior vena cava. In addition to this vein the right horn receives the right duct of Cuvier (from the body-wall of the right side) and the left horn of the sinus, which conveys the blood from the left duct of Cuvier. Later, when transverse connexions are established between the cardinal veins of the two sides (fig. 198), the blood from the body-wall of the left side reaches the heart *viâ* the veins of the right side. The left duct of Cuvier then becomes much reduced in size and forms the oblique vein of the left atrium, while the left horn itself persists as the coronary sinus.

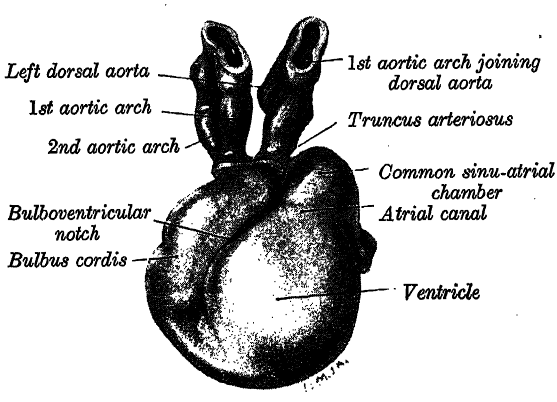
The right horn of the sinus venosus opens into the right atrium through its dorsal and caudal walls. The orifice, which is elongated and often slit-like, is guarded by two muscular folds which are termed the *right* and *left venous valves* (fig. 183). These two valves meet at the cephalic end of the orifice and become

FIG. 175.—A horizontal section through the pericardium and developing heart of the embryo shown in fig. 174. (After Carl L. Davis.) The arrows indicate the directions in which the dorsilateral recesses of the pericardium deepen so as to define the transient dorsal mesocardium.



continuous with a fold which projects into the atrium from its roof and is termed the *septum spurium* (fig. 180). At the caudal end of the orifice the two valves meet and fuse with the dorsal endocardial cushion of the atrial canal (p. 138). The cephalic part of the right venous valve disappears, but its position is indicated in the adult heart by the crista terminalis ; its caudal part forms the valve of the coronary sinus and most of the valve of the inferior vena cava. The medial (or left) end of the valve of the inferior vena cava is formed by a small

FIG. 176.—The heart of a 0·95 mm. rabbit embryo. Viewed from the ventral side. (Drawn from a model by G. Born.)



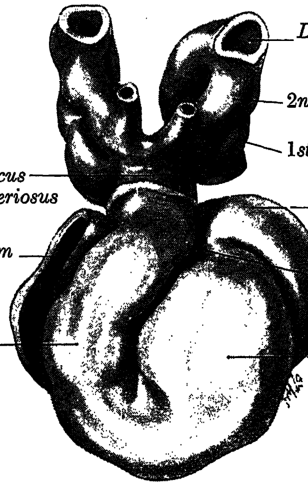
fold which projects from the dorsal wall of the sinus venosus and is termed the *sinus septum*. In the embryo the sinus septum intervenes between the orifice of the vena hepatis communis and the opening of the left horn of the sinus.

The left venous valve blends with the right side of the atrial septum and no trace of it can be seen in the adult heart.

As the venous valves undergo these changes the right horn of the sinus venosus becomes incorporated in the right atrium and forms its dorsal wall, medial to the crista terminalis. This part of the adult atrium is often termed the *sinus venarum*.

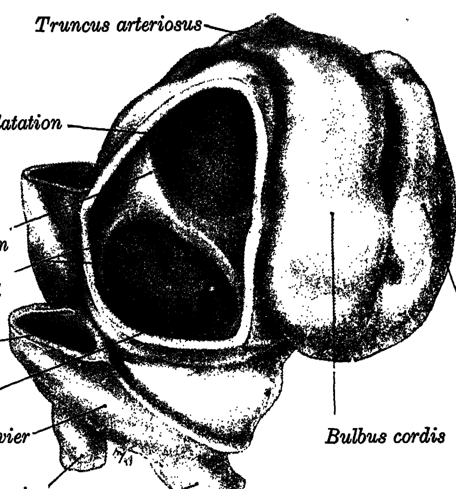
The atria.—As already stated, the common atrium is derived from the ventri-cranial part of the sinu-atrial chamber. It receives the opening of the sinus venosus in its dorsicaudal part to the right of the median plane, while

Fig. 177.—The heart of a 1·7 mm. rabbit embryo. Viewed from the ventral side. (Drawn from a model by G. Born.)



its ventral part communicates with the ventricle through the atrial canal, which lies at first to the left of the median plane. As the atrial canal moves towards the median plane, swellings appear in its ventral and dorsal walls

Fig. 178.—The heart shown in fig. 177, viewed from the right side and slightly from the ventral aspect. The right wall of the common sinu-atrial chamber has been removed to show the interior. (Drawn from a model by G. Born.)



in the space between the endothelial tube and the myo-epicardial mantle. They are termed the *atrioventricular endocardial cushions* and consist of a simple mesenchyme which stains darkly with hæmatoxylin. They encroach

Fig. 179.—The heart of a human embryo, about six weeks old. Dorsal aspect. (From a model by His.)

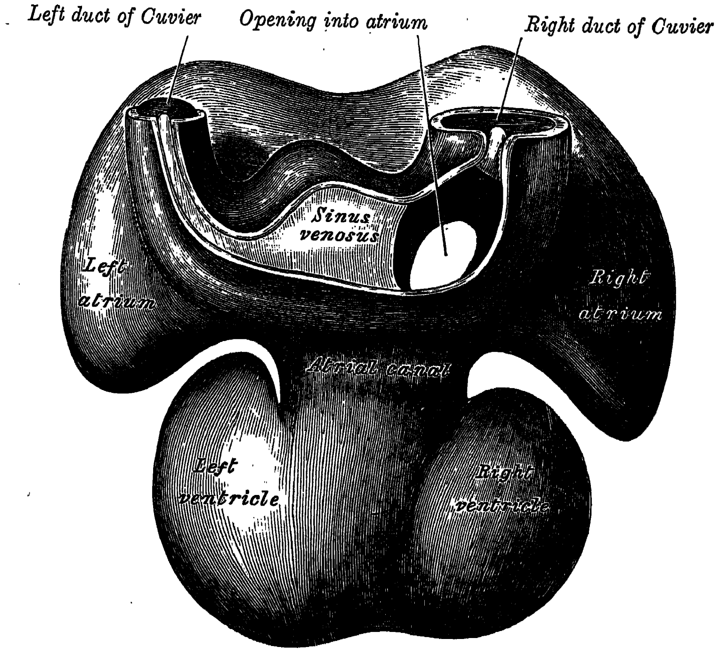
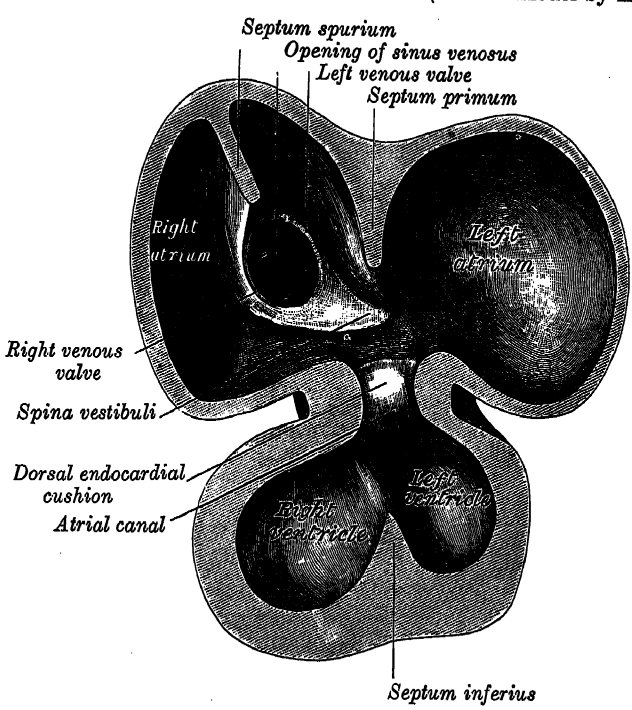
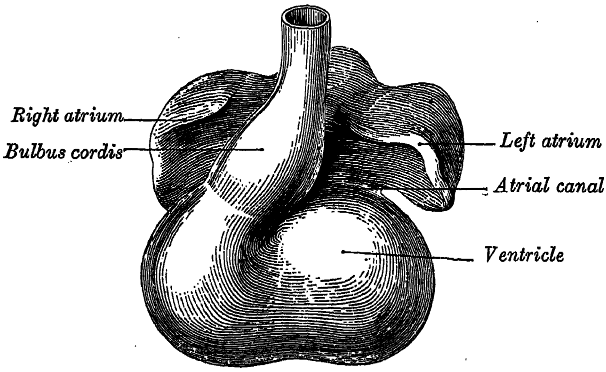


Fig. 180.—The heart of a human embryo, about thirty-eight days old. The interior of the dorsal half. (From a model by His.)



on the canal and eventually fuse with each other, leaving a relatively small orifice on each side. The fused cushions constitute the *septum intermedium*

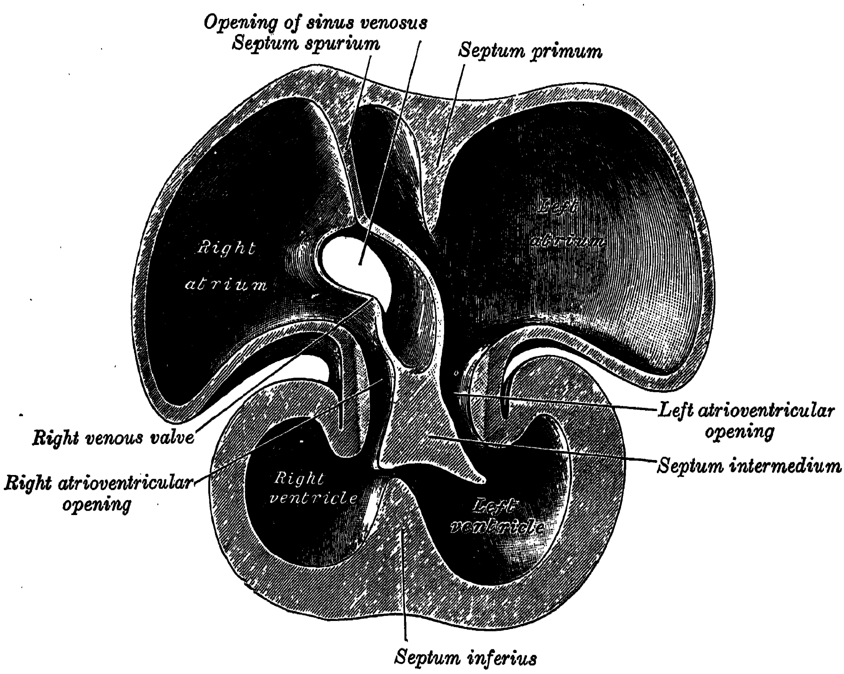
Fig. 181.—A heart showing the expansion of the atria. (From an Ecker-Ziegler model.)



(of His), and the two small orifices become the right and left atrioventricular openings.

The internal separation of the two atria is effected by the growth of two septa. The first to appear is termed the *septum primum*, and it grows from the

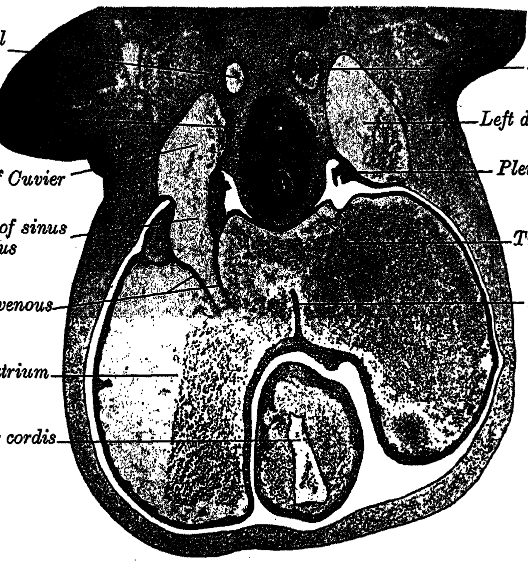
Fig. 182.—The heart of a human embryo, about six weeks old. The interior of the dorsal half. (From a model by His.)



dorsal wall as a sickle-shaped fold (fig. 184, *A*) which is separated from the left venous valve by an interval named the *intersepto-valvular space*. The ventral horn of the sickle reaches the ventral atrio-ventricular cushion, and the dorsal horn reaches the dorsal cushion. Ventral and caudal to the advancing edge of the septum the two atria communicate through the *ostium primum* (of Born) (fig. 182). Free passage of blood from the right atrium to the left is essential

throughout fœtal life, and, therefore, as the ostium primum becomes reduced in size, the dorsal part of the septum primum breaks down and a new communication, termed the *ostium secundum*, is formed between the two atria. The ostium primum becomes occluded completely by the fusion of the edge of the septum primum with the fused atrio-ventricular cushions, and it should be noted that this fusion occurs in the median plane. The ostium secundum enlarges sufficiently to ensure the free passage of blood from the right atrium to the left, and it persists throughout intra-uterine life as the *foramen ovale*. At first this opening is situated in the cephalic and dorsal portion of the septum primum

FIG. 183.—Transverse section of a human embryo, 8 mm. long. Observe how the atria bulge forwards on either side of the bulbus cordis, and compare with fig. 182. The septum primum has broken down in its dorsal portion and the two atria communicate through the foramen ovale secundum.

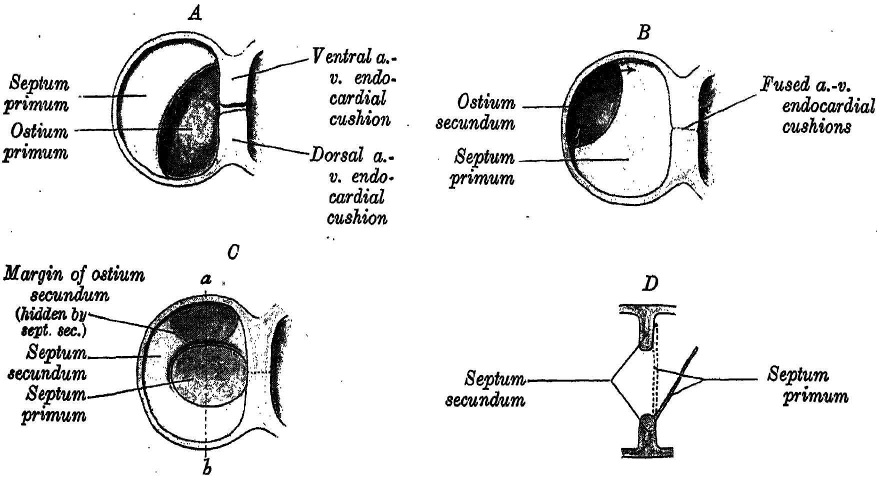


but its position becomes modified until it lies in its cephalic and ventral part (fig. 184, *C*). Towards the end of the second month the muscular wall of the atrium becomes inflected to form a crescentic septum on the right side of the septum primum. This inflection is termed the *septum secundum*, and it involves more than the whole width of the intersepto-valvular space, so that the dorsal attachments of the septum primum and the left venous valve are carried into the interior of the atrium (fig. 185) on its left and right surfaces respectively. The horns of the septum secundum fuse with the septum intermedium and the adjoining part of the septum primum. Its intervening, free, portion overlaps the foramen ovale (fig. 184, *D*) so that the septum primum can act as a flap-like valve. As the blood-pressure is greater in the right atrium than it is in the left, the blood flows from right to left, but not in an opposite direction. After birth the intra-atrial pressures are equalised, and the free edge of the septum primum is therefore kept in contact with the left side of the septum secundum and fusion occurs. Not infrequently the fusion is incomplete, but the opening left is usually small and valvular, and has no functional significance.

At an early stage in the development of the septum primum a single, common pulmonary vein can be identified opening into the caudal part of the dorsal wall of the left atrium close to the septum. This trunk is formed by the union of a right and a left pulmonary vein, and each of these is formed in turn by two small veins issuing from the developing lung-bud. Subsequently the common trunk and the two veins forming it expand and are incorporated in the left atrium to form the greater part of its cavity. This expansion reaches as far

as the orifices of the four veins, which thus open separately into the left atrium. During the second month the two atria bulge ventrally one on each side of the

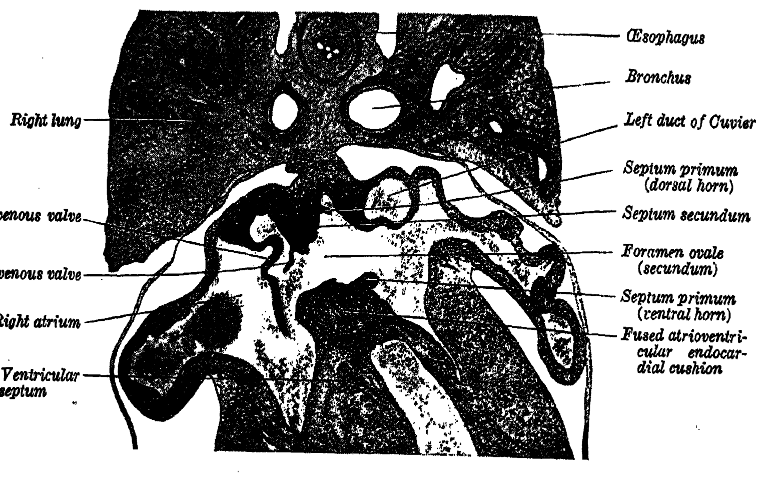
FIG. 184.—Diagrams representing three stages in the development of the atrial septum, viewed from the right side. The heart has been divided in its long axis to the right of its middle line and only the atria and the adjoining part of the ventricular cavity are depicted.



A. The septum primum has not yet obliterated the original communication between the two atrial diverticula and the atrioventricular endocardial cushions have not yet fused. *B*. The atrioventricular endocardial cushions have fused with each other and with the septum primum, which has broken down in its dorsal part. The foramen ovale secundum, thus formed, subsequently moves in the direction of the arrows. *C*. The septum secundum has formed and hides the foramen ovale secundum, the margins of which are indicated by the curved, dotted line. *D*. A section through *C* along the line *ab* to show the valve-like character of the foramen ovale secundum. When the pressure in the right atrium exceeds that in the left atrium, blood passes from the right to the left side of the heart, but when the two pressures are equal the septum primum assumes the position indicated by the dotted outline.

bulbus cordis, which lies in a groove on their ventral surface (fig. 183). These projecting parts of the atria form the auricles of the adult heart, while their dorsal parts expand to form the atria proper.

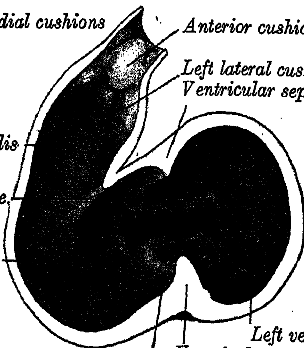
FIG. 185.—Transverse section through the thorax of a 21 mm. human embryo, showing the inflexion of the muscular atrial wall to form the septum secundum. Observe the vacuolated condition of the œsophagus which is characteristic at this stage.



The ventricles, bulbus cordis and the truncus arteriosus.—The process of separation of the two ventricles is intimately related to the separation of the

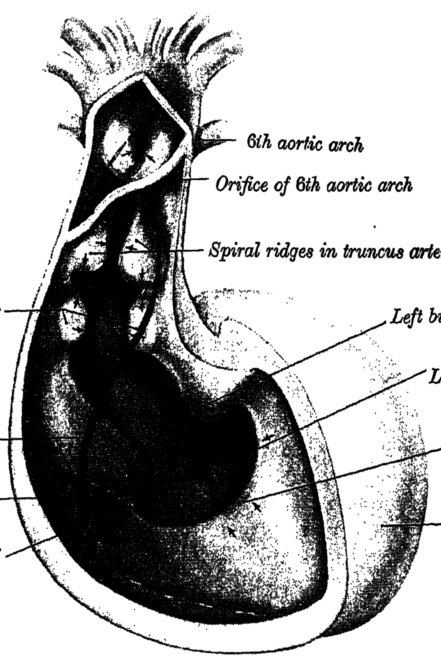
aortic and pulmonary orifices at the distal end of the bulbus and to the subdivision of the truncus arteriosus into pulmonary and aortic channels. These

FIG. 186.—A diagram showing the relations at an early stage between the atrioventricular opening and ventricles, the cavity of the bulbus cordis, and the bulboventricular ridge. The endocardial cushions at the distal end of the bulb are shown in a more differentiated state than they really exhibit at this stage. (J. Ernest Frazer.)



two processes are so closely interdependent that the history of the truncus arteriosus will be dealt with in this section, although it takes no part in the

FIG. 187.—A diagram to show the mode of formation of the septa which separate the aortic and pulmonary channels in the embryonic heart. The red arrow indicates the aortic channel, and the blue arrow, the pulmonary. The small black arrows indicate the directions of growth. (Drawn from a plasticine model made by Dr. J. Whillis.)



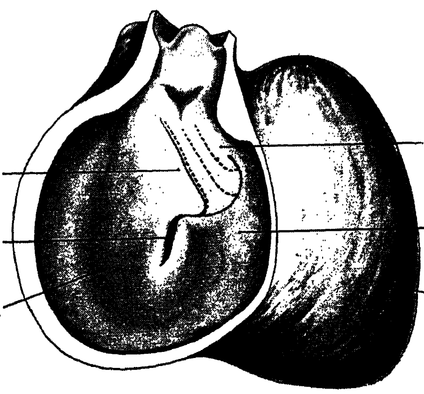
formation of the heart itself, and both will be considered before the separation of the two ventricles is described.

Four endocardial cushions—a ventral, a dorsal, a right and a left—form in the distal part of the bulbus, and the right and left cushions fuse to constitute

the *distal bulbar septum.* This septum separates a ventral, or pulmonary, orifice from a dorsal, or aortic, orifice, and later the cushions become modified to form the semilunar valves.

The separation of the pulmonary trunk from the aorta is a more complicated process. Two ridge-like thickenings project into the interior of the truncus arteriosus. Proximally, the ridges are placed on the lateral walls of the vessel, but as they are traced away from the heart, the right ridge passes obliquely on to the ventral wall and then on to the left wall, while the left ridge extends on to the dorsal wall and then on to the right wall (fig. 187). The ridges are therefore spiral and their fusion forms the *spiral aortopulmonary septum.* At its proximal end this septum meets and fuses with the distal bulbar septum, and on account of its spiral character the pulmonary trunk, which lies ventral to the aorta at its orifice, curves round to its left side as it ascends, and finally lies dorsal to it (fig. 187). At its distal end the aortopulmonary septum meets the dorsal wall of the truncus arteriosus headwards of the point where it is joined

FIG. 188.—A diagram to show the completion of the separation of the aortic and pulmonary channels. The dotted lines indicate successive positions of the left bulbar ridge as it fuses with the free edge of the ventricular septum and approaches the right bulbar ridge (J. Ernest Frazer).



by the sixth pair of aortic arches, and as a result these arches become branches of the pulmonary trunk, while the other aortic arches are left in communication with the aorta (fig. 187).

The separation of the two ventricles from each other has to be effected in such a way as to leave the right ventricle in communication both with the right atrium and with the pulmonary artery, and the left ventricle in communication both with the left atrium and the aorta. On account of the complicated character of the changes which are necessary three distinct factors contribute to the formation of the adult ventricular septum, viz. :—(*a*) the *ventricular septum* (or *septum inferius* of His), (*b*) the *proximal bulbar septum,* and (*c*) the *atrioventricular endocardial cushions* (*septum intermedium* of His).

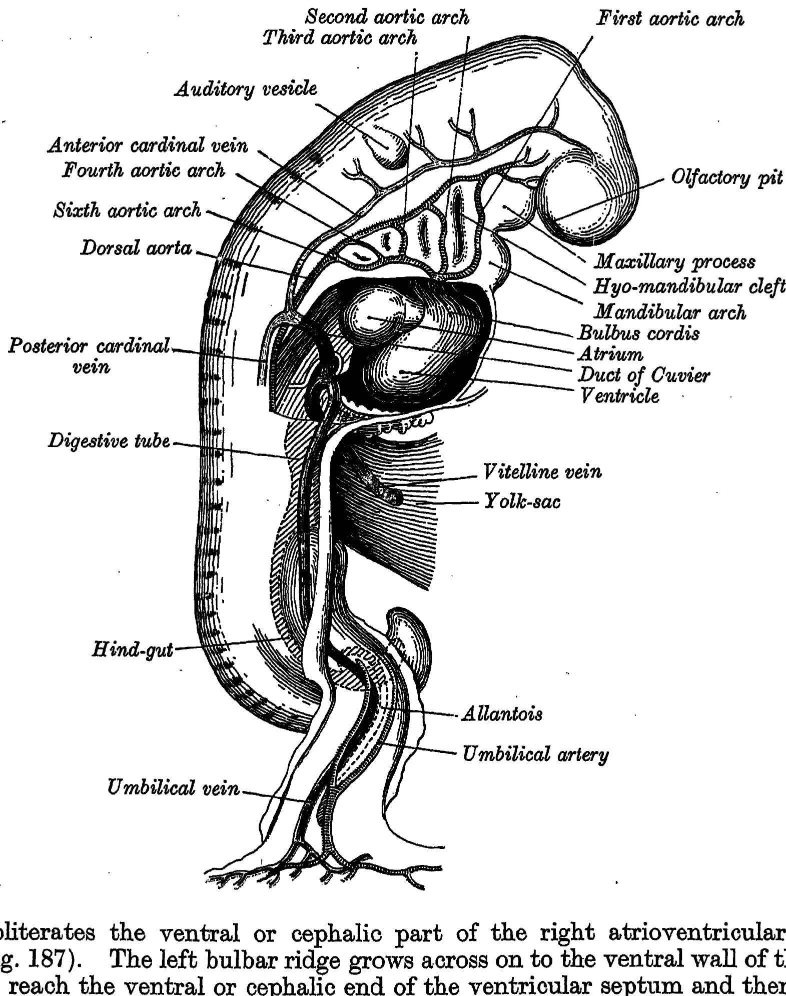
(*a*) During the fifth week the right and left ventricles are indicated as slight projections on the surface of the common ventricle. In the inside of the heart a crescentic ridge indicates the separation between them and, as the heart enlarges, this ridge deepens to form the *ventricular septum.* Dorsally it meets the dorsal endocardial cushion of the atrial canal *near its right extremity* and fuses with it. The septum has a free sickle-shaped margin, which bounds the circular interventricular foramen (fig. 187).

At first the bulbo-ventricular junction is marked by a distinct notch on the outside of the heart (fig. 186), and on the inside of the heart there is a corresponding *bulbo-ventricular ridge.* This ridge is interposed between the atrioventricular orifice and the caudal part of the bulb (fig. 186), and its absorption is essential for the development of the four-chambered heart. As a result, partly of the absorption of the bulbo-ventricular ridge and partly of the growth of the atrioventricular region, the right extremity of the atrial canal comes to

lie below the orifice of the bulb (fig. 187). This alteration in the relative positions of the structures concerned occurs while the ventricular septum is forming, and paves the way for the completion of the process of ventricular partition.

(*b*) The *proximal bulbar septum* separates the bulbus cordis into pulmonary and aortic channels, and is formed by the *right* and *left bulbar ridges*, which are in continuity with the corresponding bulbar endocardial cushions. The right bulbar ridge grows across on to the dorsal wall of the bulb and the right extremity of the fused atrioventricular endocardial cushions to reach the dorsal end of the free, sickle-shaped edge of the ventricular septum, and in doing so

FIG. 189.—A human embryo 4·2 mm. long. Right lateral aspect. (After His.)



obliterates the ventral or cephalic part of the right atrioventricular orifice (fig. 187). The left bulbar ridge grows across on to the ventral wall of the bulb to reach the ventral or cephalic end of the ventricular septum and then grows along its free margin until it meets and fuses with the right bulbar ridge.* As a result of the formation of this proximal bulbar septum the ventral part of the bulb becomes incorporated in the right ventricle and forms its infundibular part (conus arteriosus). The dorsal part of the bulb becomes absorbed almost entirely, but its position is indicated by the dorsal wall of the aortic vestibule, which, however, is formed to a large extent by the fused atrioventricular endocardial cushions. It will be clear, from the directions of growth of the two ridges, that the proximal bulbar septum is twisted, and this is necessitated by the fact that it has to connect two septa—the distal bulbar septum and the ventricular septum—which do not lie in the same plane.

(*c*) At the time of their fusion the atrioventricular endocardial cushions are

* See footnote *, p. 146.

very large relative to the size of the atrioventricular orifices. The atrial septum meets the atrial surface of the cushions at their centre, but the ventricular septum meets them near their right extremity. It follows that a portion of the fused cushions intervenes between the right atrium and the left ventricle, and it is this portion which forms the right part of the dorsal wall of the aortic vestibule (*membranous part of atrial septum*, p. 681). The membranous part of the ventricular septum, which is continuous behind with the membranous part of the atrial septum in the adult heart, is formed where the caudal end of the right bulbar ridge crosses the right extremity of the fused atrioventricular endocardial cushions to join the ventricular septum. The persistence of a communication between the two ventricles is due to arrest of development in this region.*

It should be observed that a part of the circular orifice which lies above the ventricular septum (fig. 187) becomes incorporated in the aortic vestibule and thereafter serves to connect the left ventricle with the aortic channel.

The valves of the heart.—The atrioventricular valves develop as endothelial projections directed towards the ventricles at the atrioventricular orifices. From the first they are connected with the ventricular musculature at their bases and, as growth proceeds and the flaps become enlarged, these muscular trabeculæ become freed and constitute the musculi papillares, their extremities being converted into the fibrous chordæ tendineæ. The aortic and pulmonary valves are formed from the four endocardial cushions which appear at the distal end of the bulbus cordis. The completion of the distal bulbar septum results in the division of each lateral cushion into two parts, so that the number of thickenings is increased to six, of which three are associated with the pulmonary orifice and three with the aortic. These thickenings form the rudiments of the aortic and pulmonary valves, while the pouches between the valves and the walls of the vessels gradually enlarge and form the sinuses of the aorta. At first, therefore, one cusp of the pulmonary valve lies anteriorly and the other two posterolaterally, whereas one cusp of the aortic valve lies posteriorly and the other two anterolaterally. Before birth the heart becomes rotated to the left so that the pulmonary artery assumes its permanent position to the left of, and anterior to, the aorta. This rotation also affects the relative positions of the cusps of the pulmonary and aortic valves, so that they come to occupy the positions in which they are found in the adult heart.

Applied Anatomy.—The various cardiac septa may be arrested in their development or, more rarely, the septa may form in an abnormal manner, conditions which give rise to the various forms of congenital cardiac anomalies. (*a*) The septum secundum of the atria may fail to fuse with the septum primum, rendering possible a communication between the two atria. Unless, owing to a deficiency of the septum primum, the floor of the fossa ovalis is completely or partially absent this communication is of no functional importance, because of its valvular character and the equality of the intra-atrial pressures. When free communication exists between the two atria the condition is still compatible with life and is compensated for by a marked increase in the number of the red blood-corpuscles. (*b*) The ventral part of the bulbus cordis may fail to enlarge to form a normal infundibulum (conus arteriosus). In these cases the pulmonary artery is very considerably stenosed and blood reaches the lungs through the medium of a persistent ductus arteriosus. At the same time the dorsal part of the bulb expands, instead of becoming absorbed, and the aorta communicates with both ventricles. The membranous part of the ventricular septum is deficient. (*c*) Transposition of the aorta and pulmonary artery is occasionally met with, and is usually associated with a more or less marked deficiency in the ventricular septum, although this structure may be complete. As the transposition may affect the topographical relationships of the two vessels to each other, or may involve their ventricular connexions, several distinct types of this anomaly can be differentiated.†

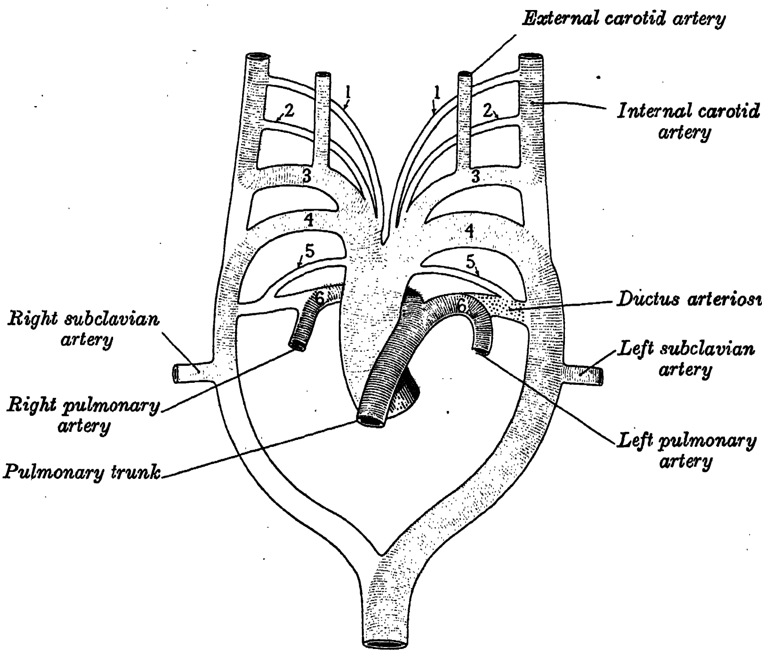
* Recent work by P. N. B. Odgers (to be published shortly in the *Journal of Anatomy*) has shown that a large part of the circular interventricular foramen is actually occluded by a proliferation from the atrioventricular endocardial cushions which fuses with the lower end of the proximal bulbar septum and with the ventricular septum. This proliferation forms the membranous part of the ventricular septum in the adult and its failure to develop results in the presence of an interventricular foramen.

† Congenital cardiac anomalies are so numerous and varied that it is impossible to give more than the merest outline. *See* Sir Arthur Keith's Hunterian Lectures, the *Lancet*, 1909, and T. Walmsley, *Quain's Anatomy*, eleventh edition, vol. iv. part iii.

The further development of the arteries.—Recent observations show that none of the main vessels of the adult arise as single trunks in the embryo. At the site of each vessel a capillary network forms, and by the enlargement of definite paths in this network the larger arteries and veins are developed. The branches of the main arteries are not always simple modifications of the vessels of the capillary network, but may arise as new outgrowths from the enlarged stem.

It has been seen (p. 134) that subsequent to the formation of the head-fold each primitive aorta consists of a ventral and a dorsal part which are continuous through the first aortic arch. The dorsal aortæ at first run caudally separately, one on each side of the notochord, but in the fourth week they fuse from about the level of the fourth thoracic to that of the fourth lumbar segment to form a single trunk—the descending aorta. Although in many animals paired

Fig. 190.—A scheme of the aortic arches and their transformations. (After Congdon.)



ventral aortæ arise from the truncus arteriosus and course headwards on the ventral surface of the pharynx, in the human embryo the ventral aortæ are fused and form a dilated vessel, termed the 'aortic sac' (Congdon).* The first aortic arches run through the mandibular arches, and caudal to them five additional pairs are developed within the corresponding visceral arches; so that, in all, six pairs of aortic arches are formed (figs. 190, 191). The fifth arches are very transitory vessels connecting the aortic sac with the dorsal ends of the sixth arches. The other arches pass between the aortic sac and the dorsal aortæ.

In fishes the aortic arches persist and give off branches to the gills, in which the blood is oxygenated. In mammals some of the arteries remain as permanent structures, while others disappear or are obliterated (fig. 190).

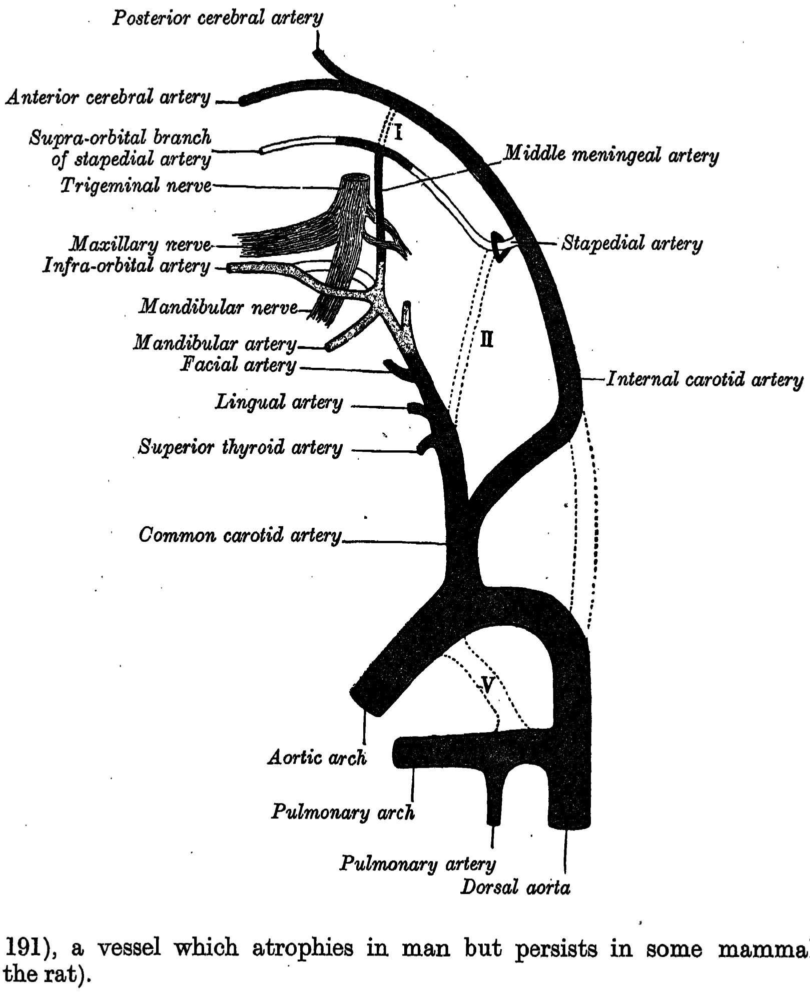
The aortic sac represents fused, paired ventral aortæ. As the embryo grows and the aorto-pulmonary septum is formed, part of the caudal end of the sac is incorporated in the trunk of the pulmonary artery. The cephalic end of the sac becomes drawn out into right and left limbs as the neck lengthens. The right limb becomes the innominate artery and the left limb forms the root

* E. D. Congdon, *Contributions to Embryology*, No. 68, 1922.

of the left common carotid artery. The remainder of the sac contributes to the formation of the arch of the aorta.

The aortic. arches.—The first and second aortic arches disappear, while the third is forming, but they are replaced by mandibular and hyoid arteries which grow into the arches from the dorsal aortæ but do not reach the aortic sac. Close to its point of origin the hyoid artery gives off the stapedial artery

FIG. 191.—A diagram showing the origins of the main branches of the carotid arteries. (Founded on Tandler by T. H. Bryce.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



(fig. 191), a vessel which atrophies in man but persists in some mammals (e.g. the rat).

The stapedial artery passes through the ring of the stapes and divides into supra-orbital, infra-orbital, and mandibular branches, which follow the three divisions of the trigeminal nerve. The infra-orbital and mandibular branches arise from a common stem, the terminal part of which anastomoses with the external carotid. On the obliteration of the stapedial artery this anastomosis enlarges and forms the (internal) maxillary artery, and the branches of the stapedial artery are now branches of this vessel. The common stem of the infra-orbital and mandibular branches passes between the two roots of the auriculotemporal nerve and becomes the middle meningeal artery; the original supra-orbital branch of the stapedial artery is represented by the orbital twigs of the middle meningeal artery.

Near its ventral end the third aortic arch gives origin to a vascular sprout which passes headwards and forms the external carotid artery. After the appearance of this vessel, the ventral end of the third aortic arch persists as the distal end of the common carotid and its dorsal end as the proximal end of

the internal carotid artery. The fourth aortic arch of the right side forms the proximal part of the right subclavian, while the corresponding vessel of the left side constitutes the arch of the aorta between the origin of the left common carotid artery and the termination of the ductus arteriosus. The fifth arch disappears on both sides. The ventral part of the sixth aortic arch of the right side persists as the proximal part of the right pulmonary artery but its dorsal part disappears. The ventral part of the sixth aortic arch of the left side is absorbed into the pulmonary trunk, while its dorsal part persists as the ductus arteriosus ; this duct remains pervious during intra-uterine life, but is obliterated after birth and forms the ligamentum arteriosum of the adult. The developing lung-buds are first supplied by a capillary plexus derived from the aortic sac. Later, this plexus becomes connected to the dorsal aorta, and this vascular connexion between the latter and the aortic sac constitutes the sixth aortic arch. The continuation of the capillary plexus to the lung-bud thereafter becomes transformed into the definitive pulmonary artery.

The dorsal aortæ.—On the cephalic side of the third aortic arches the dorsal aortæ persist and form the continuations of the internal carotid arteries ; these arteries pass to the brain, and each divides into an anterior and a posterior branch, the former giving off the ophthalmic artery and the anterior and middle cerebral arteries, while the latter turns back and joins the cerebral part of the vertebral artery. Between the third and fourth arches the right dorsal aorta disappears, but from the fourth arch to the point of origin of the seventh intersegmental artery it becomes a portion of the right subclavian artery (fig. 190). Caudal to the seventh intersegmental artery the right dorsal aorta disappears as far as the point where the two dorsal aortæ fuse to form the descending thoracic aorta. The part of the left dorsal aorta between the third and fourth arches disappears, while the remainder persists to form the descending part of the arch of the aorta. A constriction, termed the *aortic isthmus*, is sometimes seen in the aorta between the origin of the left subclavian artery and the attachment of the ductus arteriosus.

Sometimes the right subclavian artery arises from the arch of the aorta distal to the origin of the left subclavian and passes upwards and to the right behind the trachea and œsophagus. This condition may be explained by the persistence of the right dorsal aorta and the obliteration of the fourth aortic arch of the right side.

In birds the fourth aortic arch of the right side forms the arch of the aorta ; in reptiles the fourth arches of both sides persist and give rise to the double aortic arch of these animals.

The heart originally lies on the ventral surface of the pharynx, immediately caudal to the stomodæum (fig. 189) ; with the elongation of the neck and the development of the lungs it recedes within the thorax, and, as a consequence, the vessels are drawn out and the original position of the fourth and sixth aortic arches is greatly modified. Thus, on the right side the fourth aortic arch recedes to the root of the neck, while on the left side it is drawn within the thorax. The recurrent laryngeal nerves originally pass to the larynx caudal to the sixth pair of aortic arches, and are therefore pulled tailwards with the descent of these structures, so that in the adult the left nerve hooks round the ligamentum arteriosum ; owing to the disappearance of the fifth aortic arch and the dorsal part of the sixth on the right side the nerve hooks round the fourth aortic arch, i.e. the commencement of the subclavian artery.

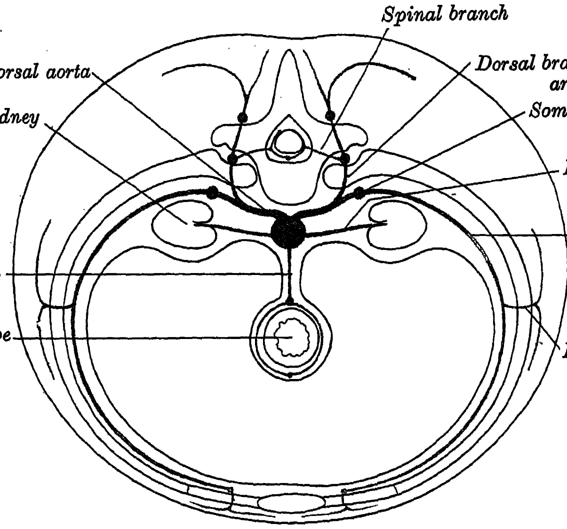
At first the aortæ are the only longitudinal vessels present, for the branches of the aortæ all run at right angles to the long axis of the embryo. Later these horizontal arteries become connected in certain situations by longitudinal anastomosing channels, and portions of these longitudinal vessels persist, forming such arteries as the internal mammary, the inferior epigastric, the gastro-epiploic, etc. Each dorsal aorta gives off segmental branches to the digestive tube (*ventral splanchnic arteries*) and to the mesonephric (Wolffian) ridge (*lateral splanchnic arteries*) and *intersegmental* branches to the body-wall (*somatic arteries*).

The *ventral splanchnic arteries* are originally paired vessels which are distributed to the wall of the yolk-sac, but after fusion of the dorsal aortæ they appear as unpaired trunks and are distributed to the primitive digestive tube.

Longitudinal anastomosing channels connect these branches along the dorsal and ventral aspects of the tube, forming dorsal and ventral splanchnic anastomoses (fig. 192). The development of these longitudinal vessels obviates the necessity for so many ventral splanchnic arteries, and these are reduced to three trunks—the cœliac, superior mesenteric and inferior mesenteric arteries. As the viscera which they supply descend into the abdomen, these vessels wander in a caudal direction; thus the origin of the cœliac artery is transferred from the level of the seventh cervical segment to the level of the twelfth thoracic, the superior mesenteric from the second thoracic to the first lumbar, and the inferior mesenteric from the twelfth thoracic to the third lumbar. The dorsal splanchnic anastomosis persists in the gastro-epiploic, pancreatico-duodenal, and the primary branches of the colic arteries, while the ventral splanchnic anastomosis forms the right and left gastric and the hepatic arteries.

The *lateral splanchnic* arteries supply, on each side, the mesonephros, the testis (or ovary) and the suprarenal gland; all these structures develop, in whole or in part, from the mesoderm of the mesonephric (Wolffian) ridge

FIG. 192.—Diagram of the segmental arteries.



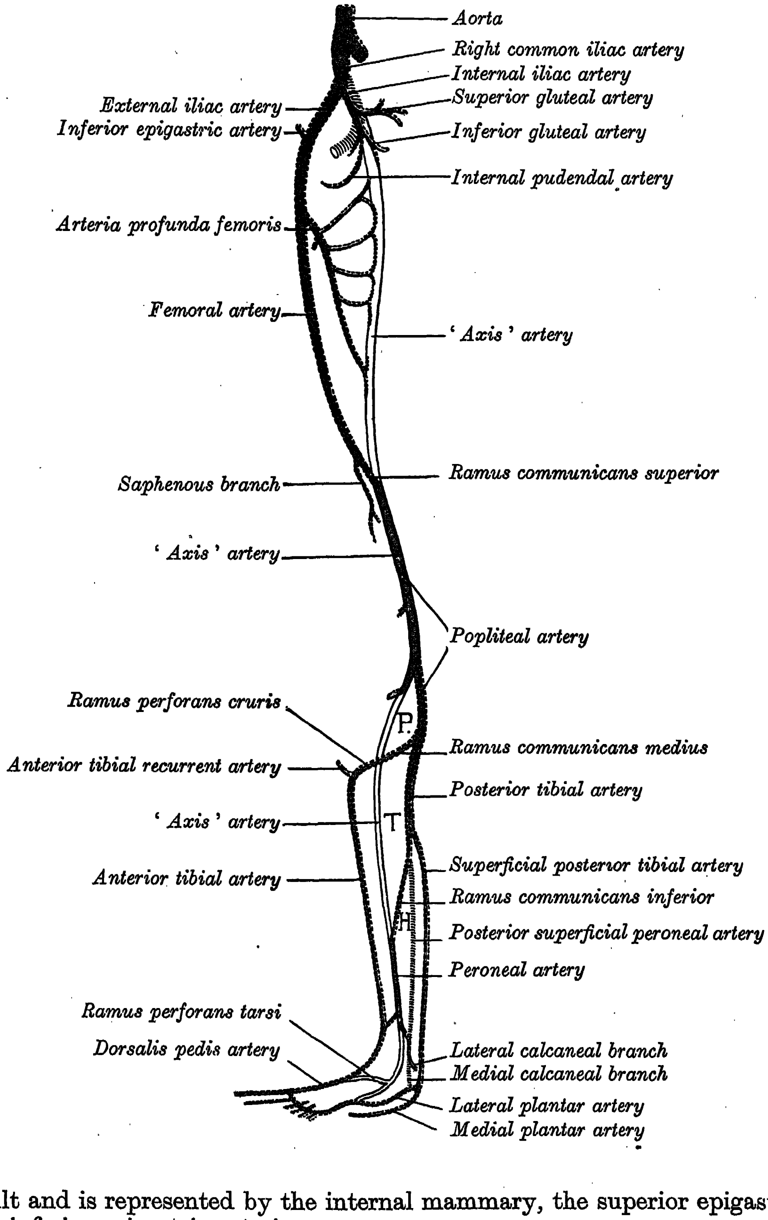
(p. 185). One testicular (or ovarian) artery and three suprarenal arteries persist on each side. The phrenic (inferior phrenic) artery arises as a branch from the first suprarenal artery, and the renal artery as a branch from the third. Additional renal arteries are frequently present and may be looked on as branches of persistent lateral splanchnic arteries.

The *somatic arteries* are intersegmental in position, and they persist, almost unchanged, in the thoracic and lumbar regions, as the posterior intercostal, subcostal and lumbar arteries. Each gives off a dorsal branch which passes backwards in the intersegmental interval and divides into medial and lateral branches to supply the muscles and superficial tissues of the back (fig. 192). In its course this dorsal branch gives off a spinal branch which enters the vertebral canal, and gives off spinal branches to the osteo-ligamentous canal and neural branches to the spinal cord. Having given off its dorsal branch the intersegmental artery runs ventrally in the body-wall, gives off a lateral branch and terminates by supplying both muscular and cutaneous branches.

Numerous longitudinal anastomoses link up the intersegmental arteries and their branches with one another. A *post-costal anastomosis* connects the dorsal branches in the interval between the neck of the rib and the vertebral transverse process. This vessel persists in the cervical region where it forms the greater part of the vertebral artery. A *post-transverse anastomosis* also connects the dorsal branches and is responsible for the greater part of the arteria profunda cervicalis. A *precostal anastomosis* connects the intersegmental

arteries beyond the origins of their dorsal branches. The ascending cervical and the superior intercostal arteries represent persistent portions of this vessel. Lastly, near the anterior median line the intersegmental arteries become linked up by a *ventral somatic anastomosis*. This vessel persists to a large extent in

FIG. 193.—A diagram to illustrate the general development of the arteries of the lower limb. The letter P indicates the position of the Popliteus; T that of the Tibialis posterior; and H that of the Flexor hallucis longus. (H. D. Senior.)



the adult and is represented by the internal mammary, the superior epigastric and the inferior epigastric arteries.

The *umbilical arteries* at first appear to be the direct continuation of the primitive dorsal aortæ and they are present in the body-stalk before any vitelline or visceral branches can be seen—an indication of the importance of the chorionic as compared with the vitelline circulation in the human embryo. After the fusion of the dorsal aortæ the umbilical arteries arise from its ventri-lateral aspect and pass medial to the primary excretory duct (Wolffian duct)

on their way to the umbilicus. Later the proximal part of the umbilical artery is joined by a vessel which leaves the aorta at its termination and passes lateral to the primary excretory duct. This new vessel, which possibly may represent the fifth lumbar intersegmental artery, constitutes the dorsal root of the umbilical artery. It gives off the axial artery of the lower limb, and, at a more proximal point, the external iliac artery. The proximal part of the umbilical artery disappears entirely, and the vessel now arises from that part of its dorsal root which lies proximal to the external iliac artery and constitutes the common iliac artery.

The arteries of the limbs.—Although a number of vessels contribute to the primitive capillary plexus of the upper limb bud, eventually only one trunk, —the subclavian—persists, and it has the position and relations of the *seventh intersegmental artery* and probably represents its lateral branch. The main trunk to the upper limb, which later forms the axillary and brachial arteries, is continued into the forearm deep to the flexor premuscle mass and terminates in a plexiform manner in the developing hand. This vessel ultimately persists as the anterior interosseous artery and the deep palmar arch. A branch from the main trunk passes dorsally between the developing radius and ulna and constitutes the posterior interosseous artery, while a second branch accompanies the median nerve into the hand, where it ends in a superficial capillary plexus. The radial and ulnar arteries are the latest arteries to appear in the forearm; at first the radial artery arises at a higher level than the ulnar and crosses in front of the median nerve, giving branches to the biceps muscle. Later, the radial artery establishes a connexion with the main trunk at or near the site of origin of the ulnar artery and the upper portion of its original stem disappears to a large extent. On reaching the hand the ulnar artery becomes linked up with the superficial palmar plexus from which the superficial palmar arch is derived, while the median artery loses its distal connexions and becomes reduced to a very small vessel. The radial artery passes to the dorsal surface of the hand but, after giving off dorsal digital branches, it perforates the first intermetacarpal space and links up with the deep palmar arch.

Senior has recently worked out the development of the arteries of the lower limb, and the following description is based on his observations.*

The primary arterial trunk (fig. 193) or ' axis ' artery of the lower limb arises from the dorsal root of the umbilical artery, and courses along the dorsal surface of the thigh, knee and leg; below the knee it lies between the tibia and the popliteus muscle, and in the leg between the crural interosseous membrane and the tibialis posterior muscle. It ends distally in a rete plantare, and gives off a perforating artery (ramus perforans tarsi) which traverses the sinus tarsi and forms a rete dorsale. The femoral artery passes along the ventral surface of the thigh, and opens up a new channel to the lower limb. It arises from a plexus of capillaries which is connected proximally with the femoral branches of the external iliac actery, and distally with the axis artery. At the proximal margin of the popliteus the axis artery gives off a *primitive posterior tibial* and a *primitive peroneal branch*, which run distally on the dorsal surface of that muscle and on the tibialis posterior to gain the sole of the foot. At the distal border of the popliteus the axis artery gives off a *perforating branch*, which passes ventrally between the tibia and the fibula and then runs downwards to the dorsum of the foot, forming the anterior tibial artery and the arteria dorsalis pedis. The primitive peroneal artery establishes one communication with the axis artery at the distal border of the popliteus and another in its course through the leg.

The femoral artery gradually increases in size, and coincidently with this increase almost the whole of the axis artery, proximal to its communication with the femoral, disappears; the root of the axis artery, however, persists as the inferior gluteal artery.

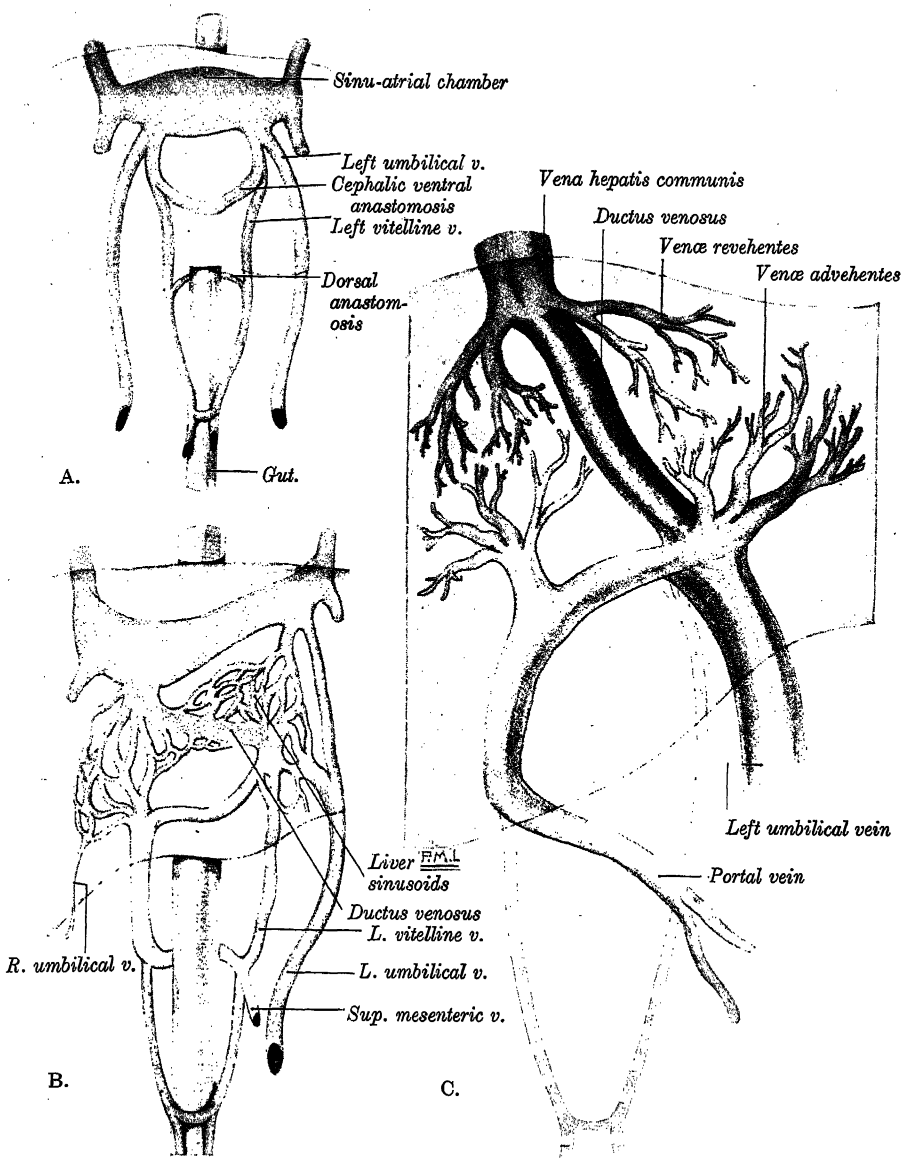
The proximal parts of the primitive posterior tibial and primitive peroneal arteries fuse, but their distal parts remain separate. Ultimately large portions of the axis artery and of the primitive peroneal artery disappear, although a

* H. D. Senior, *American Journal of Anatomy*, vol. xxv. 1919, and *Anatomical Record*, vol. xvii. 1920.

part of the former vessel is incorporated in the permanent peroneal artery. The changes are shown in greater detail in fig. 193.

The further development of the veins.—The principal veins of the embryo may be divided into two groups, visceral and parietal.

FIG. 194.—Three stages in the development of the veins of the liver.



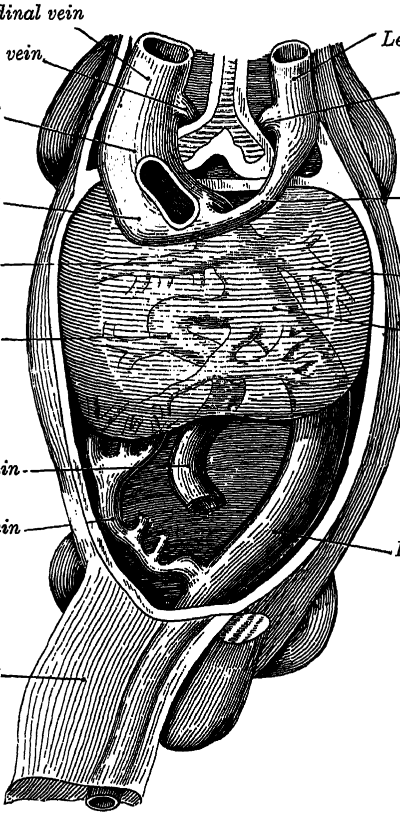
A. Pink = umbilical veins; mauve = vitelline veins.
B. Pink = umbilical veins and ductus venosus; mauve = vitelline veins and sinusoids of liver; blue = portions of vitelline veins later incorporated in the portal vein.
C. Blue = portal vein; interrupted mauve = portions of vitelline veins which disappear completely; pink = left umbilical vein and ductus venosus.

The visceral veins are the two vitelline veins bringing the blood from the yolk-sac, and the two umbilical veins returning the blood from the placenta; these four veins run through the septum transversum, and open into the sinus venosus.

The vitelline veins run upwards at first in front, and subsequently one on each side, of the digestive tube. They soon unite on the ventral surface of

the tube, and beyond this are connected to one another by two anastomotic branches, one on the dorsal and the other on the ventral surface of the duodenal portion of the intestine, which is thus encircled by two venous rings forming the figure 8 (fig. 194). The portions of the vitelline veins within the septum transversum become surrounded by the trabeculæ of the developing liver and broken up into a plexus of small capillary-like vessels, which are termed the liver *sinusoids*. Like the vitelline veins, the umbilical veins, running headwards from the umbilicus, traverse the septum transversum on their way to the sinus venosus and become involved in the growing liver. After a time the right umbilical vein entirely disappears, but the left umbilical vein, which retains

FIG. 195.—A human embryo with the heart and ventral body wall removed to show the sinus venosus and its tributaries. (After His.)

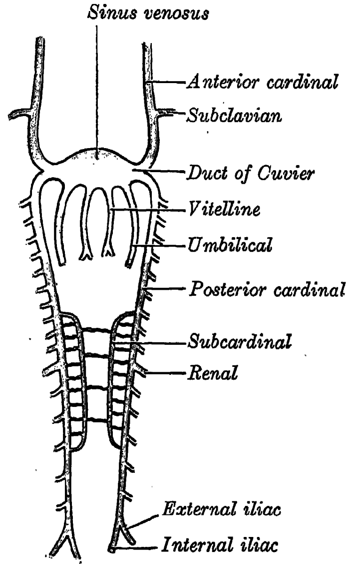


for a period its direct connexion with the left horn of the sinus venosus, pours its blood into the liver sinusoids. From the cardiac end of this vascular network, the blood flows into the horns of the sinus venosus through right and left venæ revehentes. In association with the establishment of the pulmonary circulation, venous channels develop which convey the blood from the left side of the liver to the right horn of the sinus venosus, where a large *common hepatic vein* now opens. The sinusoidal condition of the liver becomes condensed into a series of afferent vessels (*venœ advehentes*) and a series of efferent vessels (*venœ revehentes*) now leading to the common hepatic vein. In the process an oblique channel is formed which conveys most of the blood brought by the umbilical vein to the common hepatic vein. This vessel is the *ductus venosus* (fig. 194, *C*), and it plays a very important part in the fœtal circulation.

The superior mesenteric vein joins the left vitelline vein near the left extremity of the dorsal anastomosis. Later it is joined by the splenic vein, and the portal vein is thus established. Portions of the right and left vitelline veins disappear (fig. 194, *C*) and the portal vein is continued through the dorsal anastomosis, and the cephalic part of the right vitelline vein to the liver. The

intrahepatic part of the right vitelline vein becomes the right branch of the portal vein, while the cephalic ventral anastomosis and the intrahepatic part of the left vitelline vein form its left branch. The (left) umbilical vein joins the left branch of the portal vein, to which the ductus venosus is also connected. Some of the blood conveyed to the liver by the umbilical vein passes through the left venæ advehentes, but the great majority of it finds its way through the ductus venosus to the vena hepatis communis (which later forms the upper end of the inferior vena cava) and so to the right horn of the sinus venosus.

FIG. 196.—A scheme of the arrangement of the parietal veins.



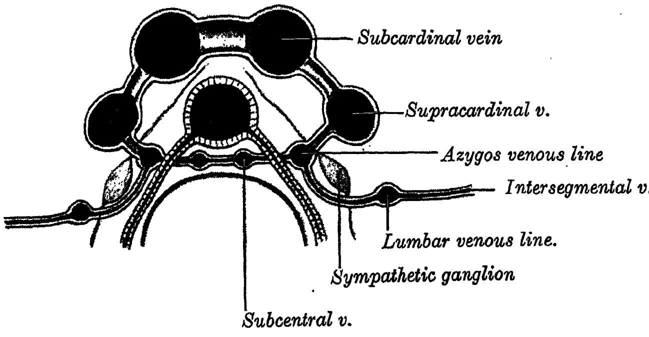
The venous drainage of the body-wall is effected at first by two large veins on each side, termed the *anterior* and *posterior cardinal veins*; the former drains the cephalic half of the embryo, and the latter the caudal half. These two veins unite to form a short vessel, termed the *duct of Cuvier*, which passes ventrally, lateral to the pleuropericardial canal (fig. 226), to gain the heart, where it joins the corresponding horn of the sinus venosus.

The *inferior vena cava* of the adult is a composite vessel, and the precise mode of development of its postrenal segment is still somewhat uncertain. Its earliest forerunner is the posterior cardinal vein, which receives the venous drainage of the lower limb bud and the pelvis and runs in the dorsal part of the mesonephric (Wolffian) ridge, receiving tributaries from the body-wall (intersegmental veins) and from the mesonephros.

A second longitudinal vein, termed the *subcardinal vein*, forms in the ventrimedial part of the mesonephric ridge and becomes connected to the posterior cardinal vein by a number of vessels which traverse the medial part of the ridge. The two subcardinal veins communicate with each other by a *preaortic anastomosis*, which later constitutes that portion of the left renal vein which crosses in front of the abdominal aorta.

The establishment of a cross anastomosis between the iliac veins, which forms a large part of the left common iliac vein in the adult, results in the preponderance of the right over the left longitudinal veins and helps to account for the subsequent disappearance of the latter.

FIG. 197.—Scheme of a composite transverse section to show the relative positions of some of the longitudinal somatic veins in the lumbar region.

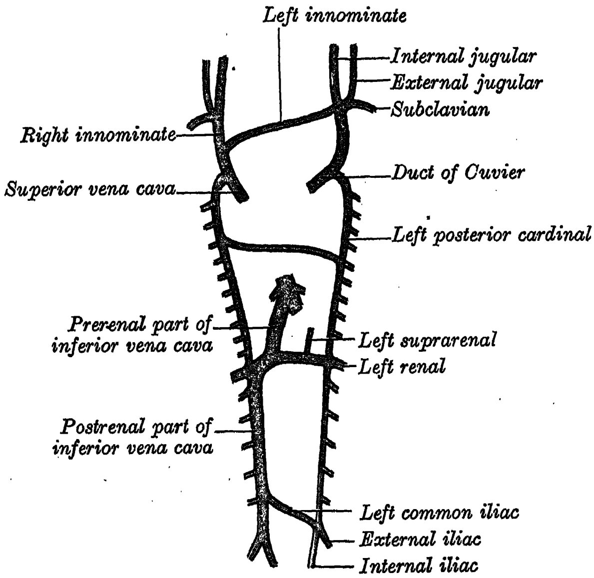


At its headward end the subcardinal vein receives the suprarenal vein on each side, but on the right side it comes into intimate relationship with the

liver. An extension of the vessel takes place in a cephalic direction and meets and establishes continuity with a corresponding new formation which is growing tailwards from the vena hepatis communis. In this way a more direct route is established to the heart and the prerenal segment of the inferior vena cava is formed.

The enlargement of the metanephros thrusts the posterior cardinal vein out of its course and the venous drainage of the mesonephric ridge is taken over by the subcardinal vein. At the same time new longitudinal channels form which take over the intersegmental venous drainage, and the whole of the posterior cardinal vein disappears with the exception of its extreme cephalic and caudal ends. These new channels are four in number on each side, but, so far as is known at the present time, only two of them persist as large vessels in the adult: (1) A longitudinal channel forms dorsilateral to the aorta and lateral to the sympathetic trunk and its branches, and takes over the intersegmental venous drainage from the posterior cardinal vein. This is the *thoraco-lumbar*

Fig. 198.—A diagram showing the development of the main cross branches between the longitudinal somatic veins.



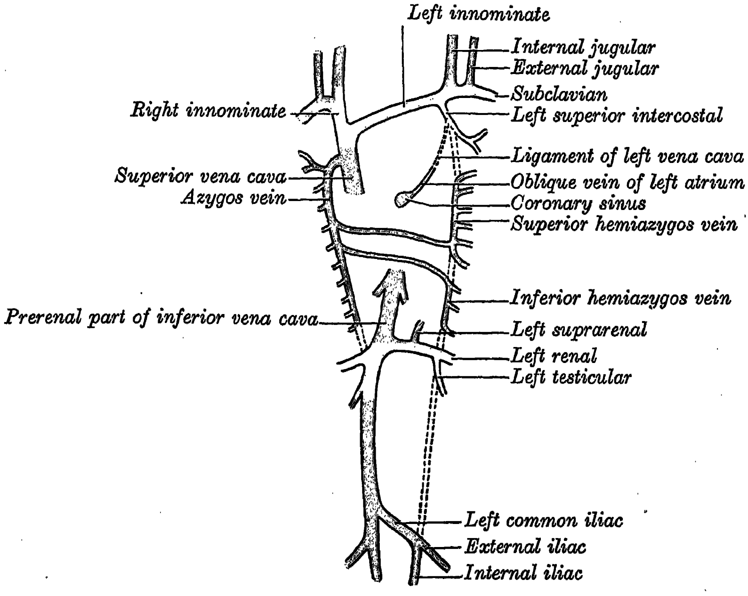
line (of Reagan). (2) A second channel is formed, also dorsilateral to the aorta but medial to the sympathetic trunk and the branches which it sends to the preaortic plexuses. This vessel constitutes the *azygos line* and, in turn, it takes over the intersegmental venous drainage from the thoraco-lumbar line. The intersegmental veins now, for the first time, reach their longitudinal channel by passing deep (medial) to the sympathetic trunk, the relationship which the lumbar and intercostal veins exhibit in the adult. At its cephalic end the azygos line joins the persistent cephalic part of the posterior cardinal vein. (3) Two *subcentral veins* are laid down directly dorsal to the aorta in the interval between the origins of the paired intersegmental arteries. These veins communicate freely with each other and with the azygos lines, and these connexions ultimately form the retro-aortic parts of the left lumbar veins. (4) The *supracardinal veins* are laid down lateral to the aorta and lateral to the sympathetic trunk and its branches to the preaortic plexuses, which therefore intervene between them and the azygos lines. These veins communicate caudally with the iliac veins and cephalically with the subcardinal veins in the neighbourhood of the preaortic intersubcardinal anastomosis. In addition, the supracardinal veins communicate freely with each other through the medium of the azygos lines and the subcentral veins. The most cranial of these connexions, together with the suprasubcardinal and intersubcardinal anastomosis, complete a venous

ring around the aorta below the origin of the superior mesenteric artery, termed by Huntington and McClure * the "*renal collar*" (fig. 197).

The right supracardinal vein persists and forms the greater part of the postrenal segment of the inferior vena cava, the continuity of the vessel being maintained by the persistence of the anastomosis between the right supracardinal and the right subcardinal in the "renal collar." The left supracardinal disappears, but the portion of the "renal collar" formed by the left supra-subcardinal anastomosis in part persists in the left renal vein.

The inferior vena cava is therefore formed, from below upwards, by (1) the right supracardinal vein, (2) an anastomosis between the right supra- and sub-

Fig. 199.—A diagram showing the completion of the development of the parietal veins.



cardinal veins, (3) the right subcardinal vein, (4) a new formation which connects the right subcardinal and the common hepatic veins, and (5) the common hepatic vein.† It should be noted that only the supracardinal part of the inferior vena cava receives the intersegmental venous drainage, and that the postrenal segment of the inferior vena cava is on a plane which lies dorsal to the plane of the prerenal segment. On this account the right inferior phrenic, suprarenal and renal arteries, which represent persistent mesonephric arteries, pass behind the inferior vena cava, while the testicular (or ovarian), which has a similar developmental origin, passes in front of it.

In some animals the right posterior cardinal vein constitutes a large part of the postrenal segment of the inferior vena cava. In these cases the right ureter, on leaving the kidney, passes medially dorsal to the vessel and then, curving round its medial side, crosses its ventral aspect. Very rarely a similar condition is found in the human subject, and indicates persistence of the right posterior cardinal vein and failure of the right supracardinal to play its normal part in the development of the vessel.

Summary of the history of the embryonic abdominal and thoracic longitudinal somatic veins.

(1) The posterior cardinal vein disappears entirely on the left side, but on the right side its cephalic end persists and forms the terminal portion of the vena azygos.

(2) The caudal part of the subcardinal vein is partly incorporated in the testicular (or ovarian) vein (McClure and Butler ‡) and partly disappears. The cephalic end of the right subcardinal vein is incorporated in the inferior vena cava and forms the right suprarenal

* S. S. Huntington and C. F. W. McClure, *Anatomical Record*, 1920.

† For a detailed account, see R. J. Gladstone, *Journal of Anatomy*, vol. lxiv. 1929.

‡ C. F. W. McClure and E. G. Butler, *American Journal of Anatomy*, vol. xxxv. 1925.

vein. The cephalic end of the left subcardinal vein is incorporated in the left renal vein and forms the left suprarenal vein.

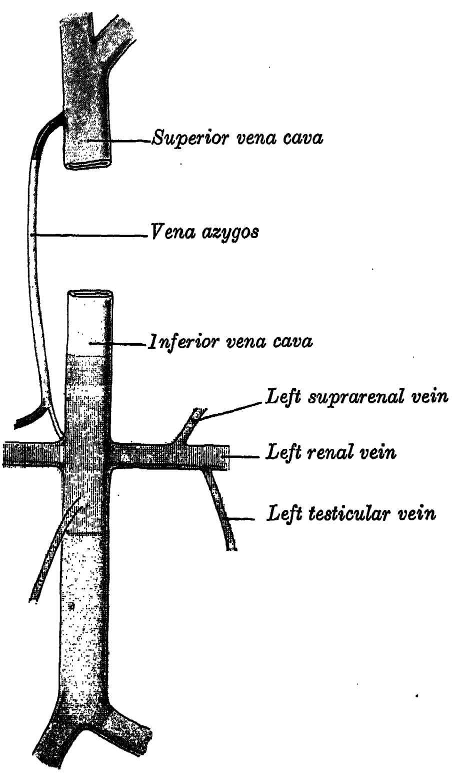
(3) The right supracardinal vein forms the postrenal segment of the inferior vena cava. The left supracardinal vein disappears entirely.

(4) The right azygos line persists in its thoracic portion to form all but the terminal part of the vena azygos. Its lumbar part can usually be identified as a small vessel which leaves the vena azygos on the body of the twelfth thoracic vertebra and descends on the vertebral column, deep to the right crus of the diaphragm, to join the posterior aspect of the inferior vena cava at the upper end of its postrenal segment. The left azygos line forms the hemiazygos veins.

(5) The subcentral veins are responsible for the formation of the retro-aortic parts of the left lumbar veins.

(6) The later history of the thoraco-lumbar lines is uncertain.

FIG. 200.—Diagram of the constituent parts of the inferior vena cava.



The supracardinal segment is shown in blue: the supra-cardinal-subcardinal segment in pink: the subcardinal segment in mauve: the subcardinal-hepatic segment in green: the hepatic segment in yellow.
The persistent part of the right posterior cardinal vein is shown in black.

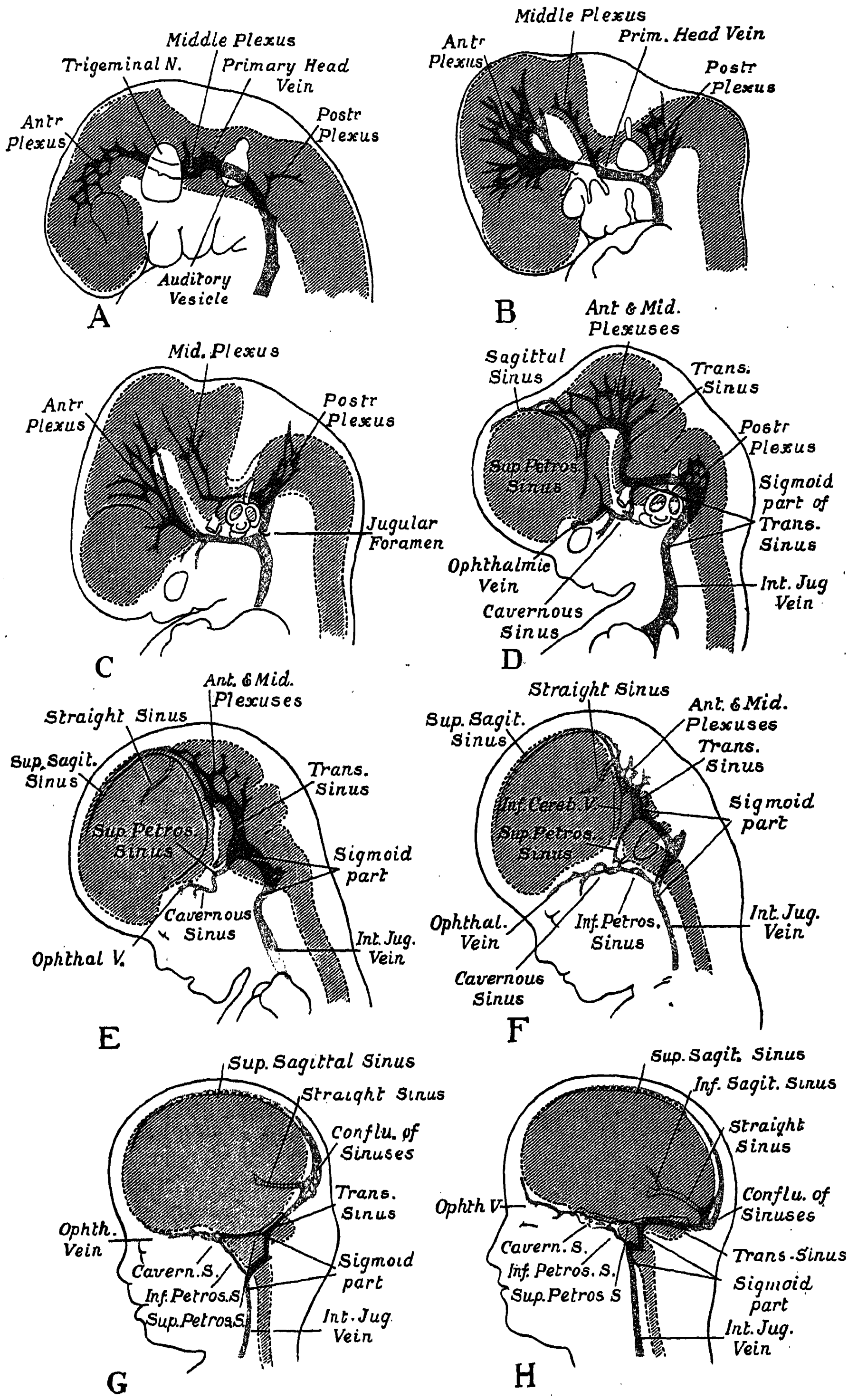
Owing to the rapid development of the head and brain the *anterior cardinal veins* become enlarged. They are further augmented by receiving the veins (*subclavian*) from the upper limb buds, and so come to form the chief tributaries of the ducts of Cuvier; these ducts gradually assume an almost vertical position in consequence of the descent of the heart into the thorax. The right and left ducts of Cuvier are originally of the same diameter, and are frequently termed the *right* and *left superior venæ cavæ*. By the development of a transverse branch (the *left innominate vein*) between the two anterior cardinal veins, the blood is carried across from the left to the right anterior cardinal (figs. 198, 199). The portion of the right anterior cardinal vein between the left innominate and the azygos vein forms the upper part of the superior vena cava of the adult; the lower part of the latter vessel (i.e. below the entrance of the azygos vein) is formed by the right duct of Cuvier. Below the left innominate vein the left anterior cardinal vein and left duct of Cuvier atrophy, the former constituting the upper part of the left superior intercostal vein, while the latter is represented by the ligament of the left vena cava and the oblique vein of the left atrium (fig. 199). The oblique vein of the left atrium passes downwards across the back of the left atrium to open into the coronary sinus, which, as already indicated, represents the persistent left horn of the sinus venosus. Right and left superior venæ cavæ are present in some animals, and are occasionally found in the adult human being.

The venous sinuses of the dura mater. The following description is based on that given by Streeter.*

The primary blood-vessels of the head consist of a close-meshed capillary plexus which is drained by anastomosing loops into a pair of veins, named the *primary head veins*. Each primary head vein (fig. 201, *A*) begins on the diencephalon, and courses along the side of the brain running medial to the trigeminal (semilunar) ganglion and lateral to the auditory vesicle; on reaching the vagus nerve it turns sharply downwards and opens into the duct

* George L. Streeter, *American Journal of Anatomy*, vol. xviii. 1915.

FIG. 201.—Profile drawings showing the development of the venous sinuses of the dura mater in human embryos from 4 mm. to birth. Their adaptation to the growth and changes in the form of the brain should be noted. A. Embryo of 4 mm.; B. Embryo of 14 mm.; C. Embryo of 18 mm.; D. Embryo of 21 mm.; E. Embryo of 35 mm.; F. Embryo of 50 mm. crown-rump length; G. Embryo of 80 mm. crown-rump length; H. At birth. (George L. Streeter.)



of Cuvier. The part of the vein which is caudal to the vagus nerve is the anterior cardinal vein, the cephalic portion of which forms the internal jugular vein. At a later stage the greater part of the original capillary plexus assumes the form of three secondary plexuses —anterior, middle and posterior (fig. 201, *B*, *C*); the middle and posterior plexuses each open by a single vein into the primary head vein. Some tributaries from the ventral part of the head also enter this vein; the most important of these are the channels from the eye-region, and these later become the ophthalmic veins.

The development of the cranium and of the brain membranes introduces further changes: the three main secondary plexuses are largely retained in association with the dura mater, while superficial portions are split off to drain the surface of the head, and deeper portions are specialized for the drainage of the brain-stem. The next series of modifications is largely due to the increase in the size of the internal ear. An anastomosing channel between the middle and posterior plexuses forms on the dorsal aspect of the auditory vesicle, and the anterior and middle plexuses unite with one another (fig. 201, *C*, *D*). A single large vein, which is the commencement of the transverse sinus, drains the anterior and middle plexuses into the new anastomosing channel (fig. 201, *D*). The posterior part of the primary head vein, i.e. the part connected with the internal jugular vein, disappears, but the anterior portion, in the region of the trigeminal nerve, is retained as the cavernous sinus, and into this the ophthalmic veins open (fig. 201, *D*, *E*). The original stem of the middle plexus, between the new anastomosing channel and the primary head vein, undergoes atrophy, but later is re-established as the superior petrosal sinus (fig. 201, *E*, *F*, *G*). The inferior petrosal sinus is a new formation, developed from a small plexus between the cavernous sinus and the internal jugular vein (fig. 201, *F*, *G*).

The transverse and sigmoid sinuses at this stage can be recognized as a composite vessel derived from (1) the stem of the conjoined anterior and middle plexuses, (2) the anastomosing channel dorsal to the auditory vesicle, and (3) the stem of the posterior plexus continued into the internal jugular vein; the second and third portions together form the sigmoid sinus.

Between the growing cerebral hemispheres extensions of the anterior and middle plexuses of both sides meet and form the *sagittal plexus*, a curtain of capillary veins which hangs down in the position of the future falx cerebri. Along the dorsal margin of this curtain the superior sagittal sinus is evolved, and this sinus usually joins the right transverse sinus; along the ventral free edge of the curtain the inferior sagittal sinus and the straight sinus are formed, the latter passing into the left transverse sinus. When the cerebral hemispheres grow backwards they carry with them the sagittal sinus; the straight sinus extends backwards through a plexus in the tentorium cerebelli, and the transference of both sinuses is continued until they arrive at their adult positions with their point of junction at the confluence of the sinuses. The posterior plexus establishes a secondary connexion with the confluence of the sinuses, loses its connexion with the sigmoid sinus, and is retained as the occipital sinus.

The external jugular vein at first drains the region behind the ear (posterior auricular) and enters the anterior cardinal as a lateral tributary. A group of veins from the face and lingual region converge to form a common vein, termed the linguofacial,* which also ends in the anterior cardinal vein. Later, cross communications develop between the external jugular and the linguofacial, with the result that the posterior group of facial veins is transferred to the external jugular vein. The cephalic vein is, for a time, a tributary of the external jugular vein, but is later diverted into the axillary vein.

At first the heart is placed directly under the head and is relatively of large size. Later it assumes its position in the thorax, but lies at first in the median plane; towards the end of pregnancy it gradually becomes oblique in direction. The atrial portion is at first larger than the ventricular part, and the two atria communicate freely through the foramen ovale. In consequence of the communication, through the ductus arteriosus, between the pulmonary artery and the aorta, the contents of the right ventricle are mainly carried into the latter vessel instead of to the lungs, and hence the wall of the right ventricle is more muscular than that of the left, a condition which persists throughout intra-uterine life. After birth more work is thrown on the left ventricle and its walls rapidly become much thicker than those of the right ventricle.

The fœtal circulation and the changes which take place in the circulation after birth are described in the section on Angiology.

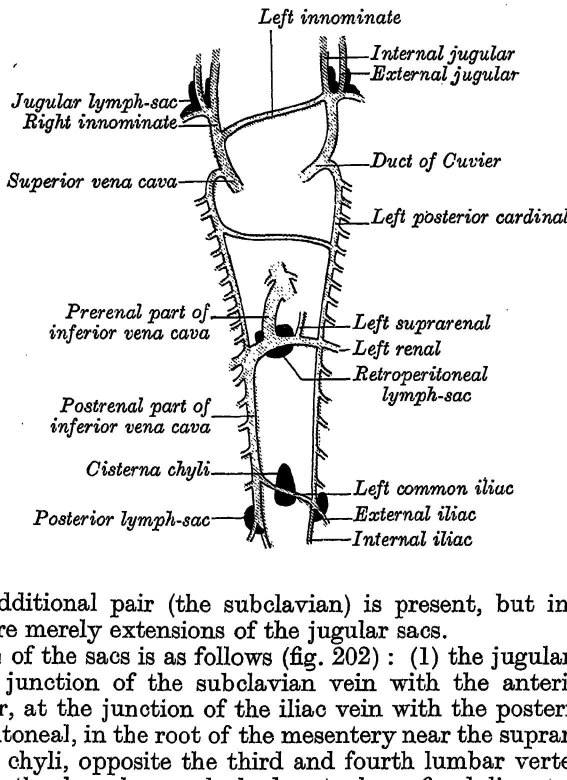
The lymphatic system.—Two different views are still current as to the initial stages in the development of the lymphatic system. According to the view

* Lewis, *American Journal of Anatomy*, vol. ix. 1909.

put forward by Huntington and McClure lymphatic spaces appear as clefts in the mesenchyme, and their lining cells take on the characters of endothelium. These spaces form capillary plexuses from which certain lymph-sacs, to be noted later, are derived. The connexions of the lymphatic with the venous system are entirely secondary. According to Sabin, however, the earliest lymph vessels arise as capillary offshoots from the endothelium of the veins, which form capillary plexuses. These plexuses lose their connexions with the venous system and become confluent to form lymph-sacs. The balance of the evidence suggests that the lymphatic system originates independently of the venous system and only acquires connexions with it at a later stage.

In the human embryo the lymph-sacs from which the lymph vessels are derived are six in number; two paired (the jugular and the posterior lymph-sacs) and two unpaired (the retroperitoneal and the cisterna chyli). In lower

FIG. 202.—A scheme showing the relative positions of the primary lymph-sacs. (Based on the description given by Florence Sabin.)



mammals an additional pair (the subclavian) is present, but in the human embryo these are merely extensions of the jugular sacs.

The position of the sacs is as follows (fig. 202): (1) the jugular, the first to appear, at the junction of the subclavian vein with the anterior cardinal; (2) the posterior, at the junction of the iliac vein with the posterior cardinal; (3) the retroperitoneal, in the root of the mesentery near the suprarenal glands; (4) the cisterna chyli, opposite the third and fourth lumbar vertebræ. From the lymph-sacs the lymph vessels bud out along fixed lines corresponding more or less closely with the course of the embryonic blood-vessels, but many arise *de novo* in the mesenchyme and establish connexions with existing vessels. In the body-wall and in the wall of the intestine,* the deeper plexuses are the first to be developed; by continued growth of these the vessels in the superficial layers are gradually formed. The thoracic duct is, phylogenetically, a bilateral structure. In man it comprises the caudal part of the right vessel, a transverse anastomosis and the cephalic part of the left vessel. According to Sabin it is formed from anastomosing outgrowths from the jugular sac and cisterna chyli. At its connexion with the cisterna chyli it is at first double, but the vessels soon join. Numerous valves are laid down in the duct during the fifth month, but many of them disappear prior to birth. Those which persist are formed in situations where the duct may

* Heuer, *American Journal of Anatomy*, vol. ix. 1909.

be subjected to pressure, e.g. where it is crossed by the œsophagus and the aortic arch.

All the lymph-sacs except the cisterna cyli are, at a later stage, divided up by a number of slender connective tissue bridges. Later they are invaded by lymphocytes and transformed into groups of lymph glands ; the lymph sinuses representing portions of the original cavity of the sac. The lower portion of the cisterna chyli is similarly converted, but its upper portion remains as the adult cisterna.

THE DEVELOPMENT OF THE DIGESTIVE AND RESPIRATORY APPARATUS

The **digestive tube.**—As already indicated (p. 69), the primitive digestive tube consists of three parts, viz. : (1) the *fore-gut,* within the head-fold and dorsal to the heart ; (2) the *hind-gut,* within the tail-fold (fig. 93, A) ; and (3) the *mid-gut,* which is intermediate in position. At first the fore-gut and hind-gut end blindly ; the cephalic end of the fore-gut is closed by the buccopharyngeal membrane ; the hind-gut ends in the cloaca, which is closed by the cloacal membrane. Both the buccopharyngeal and the cloacal membranes consist of ectodermal and entodermal layers in direct apposition with each other without the intervention of mesoderm. The wide communication between the mid-gut and the yolk-sac is gradually narrowed and drawn out to form the *vitello-intestinal duct.*

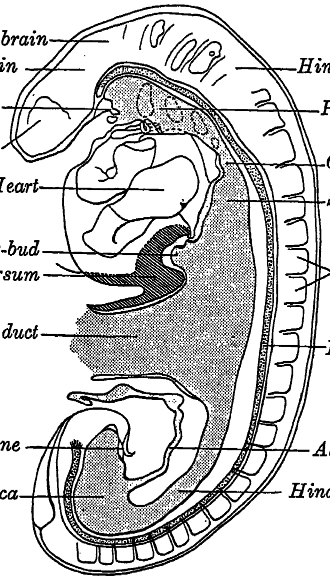
The **mouth** is developed partly from the stomodæum, and partly from the floor of the cephalic portion of the fore-gut. By the growth of the head-end of the embryo, and the formation of the head-fold, the pericardial area and the buccopharyngeal membrane come to lie on the ventral surface of the embryo (p. 69). With the further expansion of the brain, and the bulging of the pericardium, the buccopharyngeal membrane is depressed between these two prominences. This depression constitutes the *stomodæum* or *primitive mouth* (fig. 203). It is lined with ectoderm, and is separated from the cephalic end of the fore-gut by the buccopharyngeal membrane, which is formed by the apposition of the stomodæal ectoderm with the fore-gut entoderm ; at the end of the fourth week the membrane disappears, and a communication is established between the primitive mouth and the cephalic end of the fore-gut or future pharynx. No trace of the membrane is found in the adult ; and the communication just mentioned must not be confused with the permanent oro-pharyngeal isthmus (isthmus faucium). The lips, teeth, and gums are formed from the walls of the stomodæum, but the tongue is developed in the floor of the mouth and pharynx.

The visceral arches grow in a ventral direction and come to lie between the stomodæum and the pericardium ; with the completion of the mandibular arch and the development of the maxillary processes, the opening of the stomodæum assumes a pentagonal form, bounded on its cephalic side by the frontonasal process, caudally by the mandibular arches, and laterally by the maxillary processes (fig. 204). With the inward growth and fusion of the palatine processes (figs. 127, 129), the stomodæum is divided into a nasal and a buccal part. Along the free margins of the processes bounding the mouth cavity a shallow groove appears ; this is termed the *primary labial groove,* and from its floor a downgrowth of ectoderm into the underlying mesoderm takes place. Owing to the degeneration of the central cells of this ectodermal downgrowth the groove is deepened and a *secondary alveolo-labial groove* is formed, which separates the lips and cheeks from the alveolar processes of the maxillæ and mandible.

The **salivary glands** arise from the epithelial lining of the mouth. The *parotid gland* can be recognised in human embryos 8 mm. long as an elongated furrow running dorsally from the angle of the mouth between the mandibular arch and the maxillary process. The groove, which is converted into a tube, loses its connexion with the epithelium of the mouth except at its anterior end and grows dorsally into the substance of the cheek. The tube persists as the

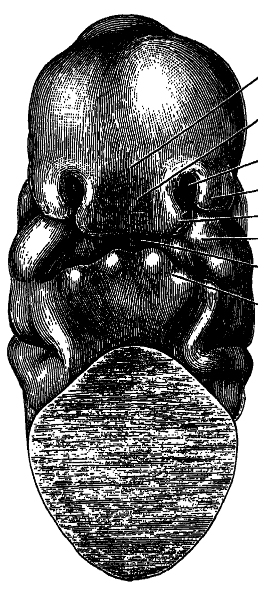
parotid duct and its blind end proliferates to form the gland. Subsequently the size of the oral fissure is reduced, and the duct opens thereafter on the inside

FIG. 203.—The digestive tube of a human embryo 2·5 mm. long. (Peter Thompson.)



of the cheek at some distance from the angle of the mouth. The *submandibular gland* (submaxillary gland) is present in human embryos, 13 mm. long, as an epithelial outgrowth from the floor of the alveololingual groove (p. 164). It increases rapidly in size by giving off numerous branching processes, which later acquire lumina. The original connexion with the floor of the mouth gradually moves ventrally, as the walls of the groove in which it lies come together at its dorsal end and the process extends ventrally to form the tubular submandibular duct (Frazer). The *sublingual gland* arises at the end of the second month as a number of small epithelial thickenings in the alveololingual groove lateral to the submandibular outgrowth.

FIG. 204.—The head-end of a human embryo in the sixth week. Ventral aspect. (From a model by K. Peter.)



The **tongue**.—Before the visceral arches meet one another at their ventral ends, a small median elevation, named the *tuberculum impar*, appears in the entodermal floor of the pharynx, and it subsequently becomes incorporated in the anterior part of the tongue. A little later two oval *lingual swellings* appear on the entodermal aspect of the mandibular arches. They meet each other in front, and caudally they converge on the tuberculum impar, with which they fuse (figs. 205, 206). A

sulcus forms along the ventral and lateral margins of this elevation and deepens to form the *alveololingual groove*, while the elevation constitutes the anterior or buccal part of the tongue.

Caudal to the tuberculum impar, a second median elevation, termed the *hypobranchial eminence* (Frazer) (*copula* of His), forms in the floor of the pharynx, and it receives the ventral ends of the fourth, the third and, later, the second visceral arches. A transverse groove separates off the caudal portion of the eminence to form the epiglottis, while its ventral portion ap-

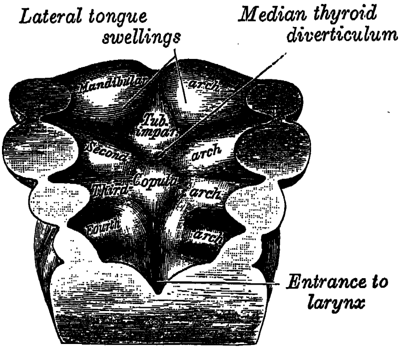


Fig. 205.—The floor of the pharynx of a human embryo in the fifth week. (From a model by K. Peter.)

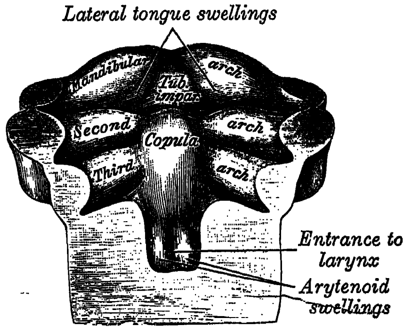


Fig. 206.—The floor of the pharynx of a human embryo at the beginning of the sixth week. (From a model by K. Peter.)

proaches the tongue rudiment, spreading ventrally in the form of a V, and blends with it to constitute the posterior or pharyngeal part of the tongue. In the process the third arch elements grow over and bury the elements of the second arch, excluding it from the tongue. As a result the mucous membrane of the pharyngeal part of the tongue receives its sensory supply from the glossopharyngeal, the nerve of the third arch. In the adult the union of the anterior and posterior parts of the tongue is marked by the V-shaped sulcus terminalis, the apex of which is at the foramen cæcum, a pit-like depression produced at the time of fusion of the constituent parts of the tongue, but also marking the site of the out-growth of the diverticulum which forms the thyroid gland.

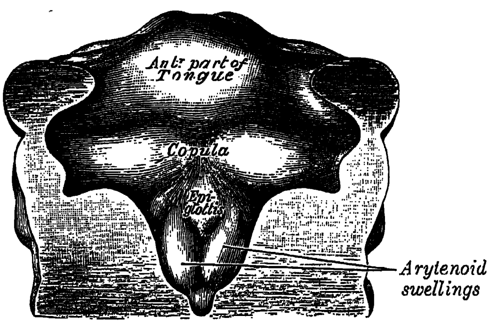


Fig. 207.—The floor of the pharynx of a human embryo, about six weeks old. (From a model by K. Peter.)

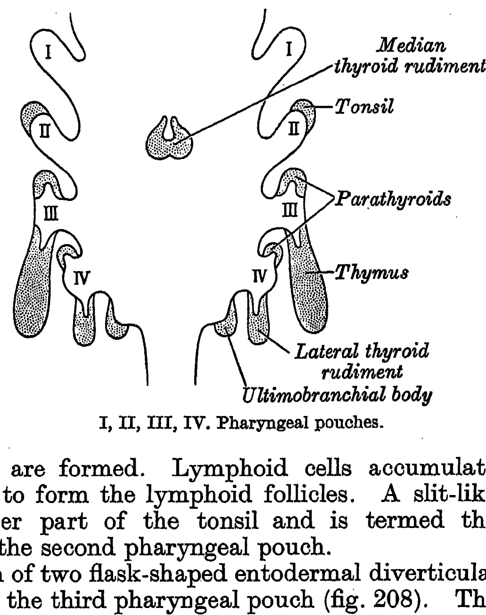
At first the tongue consists of a mass of mesoderm covered on its free surface by entoderm. During the second month the occipital myotomes migrate from their original position on the lateral aspect of the myelencephalon and invade the tongue to form its musculature. They pass ventrally round the wall of the pharynx to reach its floor and they are accompanied, necessarily, by their nerve of supply (the hypoglossal nerve), which therefore crosses superficial to both the internal carotid (dorsal aorta) and the external carotid arteries.

The composite character of the tongue is indicated by its adult innervation. The anterior or buccal part receives sensory branches from (*a*) the lingual nerve, which is derived from the (post-trematic) nerve of the first arch (mandibular nerve); and (*b*) the chorda tympani, which is the pretrematic nerve of the first arch. The posterior or pharyngeal part of the tongue receives its innervation from the glossopharyngeal, which is the nerve of the third arch. The muscles of the tongue are myotomic in origin and receive their nerve

supply from the hypoglossal nerve, which is serially homologous with the anterior nerve roots of the spinal nerves.

The **thyroid gland** is developed from a median diverticulum, which appears about the fourth week in the furrow immediately caudal to the tuberculum impar (fig. 205). It grows caudally as a tubular duct, which bifurcates and subsequently divides into a series of cellular cords, from which the isthmus and portions of the lateral lobes of the thyroid gland are developed. From the region of the ventral end of the fourth pharyngeal pouch an entodermal diverticulum grows caudally and medially. After losing its connexion with the pharnyx, it comes into contact and fuses with the dorsal and medial aspects of the lateral portion of the median thyroid rudiment. It constitutes the lateral thyroid rudiment and both median and lateral rudiments help to form the (lateral) lobe of the adult gland.* The connexion of the median diverticulum with the pharynx is termed the *thyroglossal duct*; it is obliterated at a very early stage, but the site of its connexion with the epithelial floor of the mouth is marked by the foramen cæcum. The pyramidal lobe is probably a secondary extension upwards from the developing isthmus. Occasionally portions of the thyroglossal duct persist and give rise to the formation of cysts in the median line of the neck.

FIG. 208.—A scheme showing the development of the branchial epithelial bodies. (Modified from Kohn.)



I, II, III, IV. Pharyngeal pouches.

The **tonsils** (palatine tonsils) are developed from the parts of the second pharyngeal pouches which lie between the tongue and the soft palate. The entoderm lining these pouches grows in the form of a number of solid buds into the surrounding mesoderm. These buds are excavated by the degeneration and shedding of their central cells, and by this means the tonsillar pits (crypts) are formed. Lymphoid cells accumulate around the pits, and are grouped to form the lymphoid follicles. A slit-like fissure, which cuts into the upper part of the tonsil and is termed the *intratonsillar cleft*, is a remnant of the second pharyngeal pouch.

The **thymus** appears in the form of two flask-shaped entodermal diverticula, which arise, one on each side, from the third pharyngeal pouch (fig. 208). The ventral end of each pouch gives origin to a hollow diverticulum which grows caudally into the surrounding mesoderm. In front of the aortic sac (p. 147) the two thymic rudiments meet and are subsequently united by connective tissue, but the rudiments themselves never fuse. The connexion with the third pouch is soon lost, but the stalk may persist for some time as a solid, cellular cord. By further proliferation of the cells lining the diverticula, solid buds are formed, which become surrounded and isolated by the invading mesoderm. Lymphocytes penetrate the solid lobules and soon preponderate over the epithelial elements, which later give rise to the concentric corpuscles.

The thymic rudiment closely resembles the lateral thyroid rudiment in its mode of origin. At birth the thymus weighs about 13 grams, and it increases in size up to puberty, when it averages 37·52 grams (Hammar). After puberty the gland undergoes a slow reduction in size.

The **parathyroid glands** are also derivatives of the pharyngeal entoderm. After the appearance of the thymic rudiment from the third pharyngeal pouch, the epithelium on the dorsal aspect of its neck-like connexion with the pharynx differentiates to form the *inferior parathyroid gland*. Although the connexion between the pouch and the pharynx is soon lost, the connexion between the

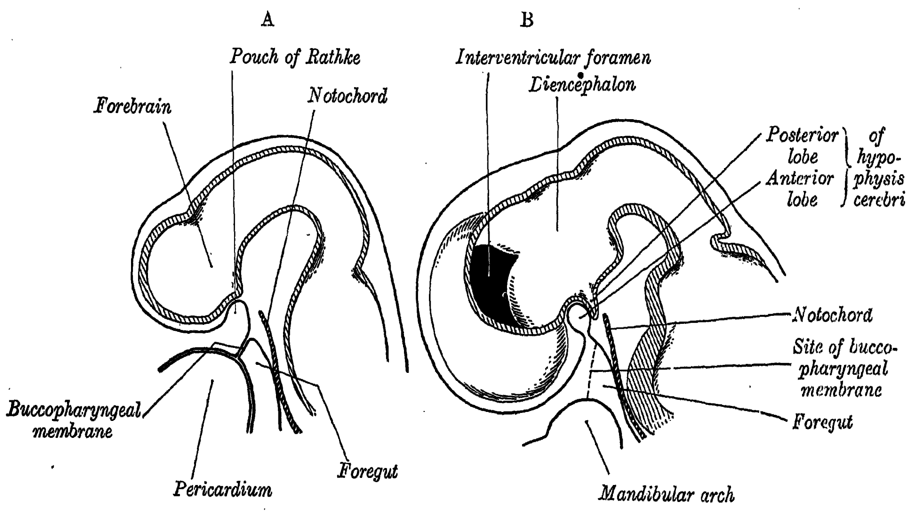
* The description of the development of the thyroid gland given here is based on the work of G. Louis Weller, jr., *Contributions to Embryology*, vol. xxiv. 1933.

thymic and parathyroid rudiments persists for some time, with the result that the latter is drawn caudally with the developing thymus. The *superior parathyroid gland* develops in a similar manner in association with the lateral thyroid rudiment and so may be ascribed to the fourth pharyngeal pouch.

It is uncertain whether the diverticulum derived from the fifth pouch and termed the *ultimobranchial body* is a distinct entity; if so, it disappears entirely at an early stage.

The **hypophysis cerebri** (pituitary body) consists of an anterior and a posterior lobe; the former is derived from the ectoderm of the stomodæum, the latter from the floor of the fore-brain. Previous to the rupture of the buccopharyngeal membrane a pouch-like diverticulum appears in the ectodermal lining of the roof of the stomodæum. This diverticulum (*pouch of Rathke*) (fig. 209) is the rudiment of the anterior lobe of the hypophysis; arising immediately ventral to the cephalic border of the buccopharyngeal membrane, it extends upwards in front of the cephalic end of the notochord, and comes into contact with the under surface of the fore-brain. It is then constricted off to form

FIG. 209.—Schematic sagittal sections of heads of early embryos to show first stages in the development of the hypophysis cerebri.



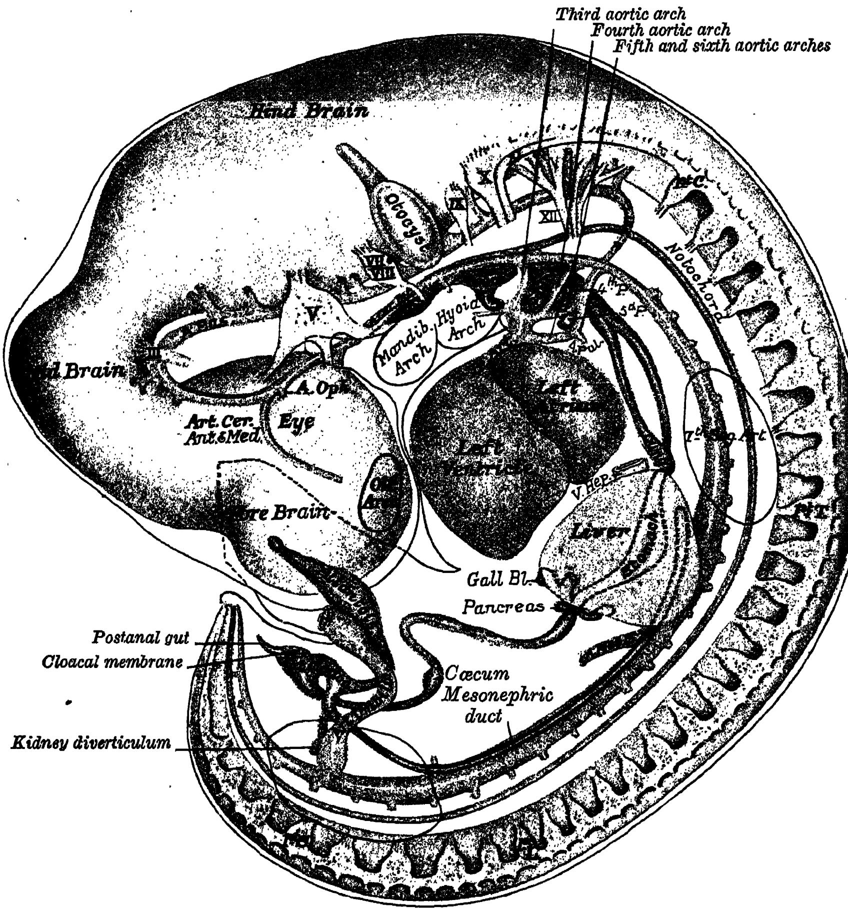
a closed vesicle, but remains for a time connected to the ectoderm of the stomodæum by a solid cord of cells. Masses of epithelial cells form on each side and in the ventral wall of the vesicle, and by the growth of a stroma from the mesenchyme between the masses the development of the anterior lobe of the hypophysis is completed. A canal (*craniopharyngeal canal*) sometimes runs from the anterior part of the hypophyseal fossa of the sphenoid bone to the under surface of the skull, and marks the original position of Rathke's pouch; and traces of the stomodæal end of the pouch are occasionally present at the junction of the septum of the nose with the palate (Frazer). Just behind Rathke's pouch a hollow diverticulum grows towards the mouth from the floor of the diencephalon. This neural outgrowth forms a funnel-shaped sac, the walls of which increase in thickness so as to obliterate the contained cavity except at its upper end, where it persists as the *infundibular recess* of the third ventricle. Formed in this way the *posterior lobe* of the hypophysis becomes invested by the anterior lobe, which extends dorsally on each side of it. In addition, the anterior lobe gives off two processes from its ventral wall which grow along the infundibulum and fuse to surround it, coming into relation with the tuber cinereum and constituting the *tuberal portion* of the hypophysis. The original cavity of the stomodæal diverticulum remains as a cleft and can be identified readily in sagittal sections through the gland in the adult. The dorsal wall of the stomodæal part, which remains thin, fuses with the adjoining part of the posterior lobe and forms the *pars media*. In

some of the lower animals the posterior lobe contains nerve-cells and nerve-fibres, but in man and the higher vertebrates it consists only of neuroglial tissue.

A small entodermal diverticulum, named *Seessel's pouch,* projects towards the brain from the cephalic end of the fore-gut, close to the buccopharyngeal membrane. In some marsupials this pouch forms a part of the hypophysis but, in man, it disappears entirely.

The **pharynx** is formed from the cephalic end of the fore-gut, and the visceral arches and pharyngeal pouches play an important part in its development. The

FIG. 210.—A human embryo of 7 mm. greatest length. Left lateral aspect. (From a reconstruction by P. Thompson.)



entodermal aspect of the mandibular arch in its dorsal part contributes to the formation of the lateral wall of the nasal pharynx in front of the orifice of the pharyngo-tympanic (auditory) tube. The ventral end of the first pouch becomes obliterated, but its dorsal end persists and deepens as the head enlarges. It remains in close relationship with the ectoderm of the dorsal end of the first cleft (p. 97) and, together with the adjoining lateral part of the pharynx and dorsal part of the second pharyngeal pouch, constitutes the *tubotympanic recess,* which forms the tympanic cavity and the pharyngo-tympanic tube (p. 131). The site of the second arch is partly indicated by the palato-glossal arch, but its dorsal end is separated from its ventral end by the forward growth of the third arch, which obliterates the intermediate part (Frazer). It is believed that the site of the second pharyngeal pouch is represented by the intratonsillar cleft, around which the tonsil is developed. This cleft is sometimes incorrectly termed the supratonsillar fossa. The third arch forms the pharyngo-epiglottic fold, and its dorsal end takes part in the formation of the floor of the pharyngo-

tympanic tube (Frazer). From the third pouch the thymus and the inferior parathyroid are developed (p. 165). The ventral ends of the fourth arches fuse with the posterior part of the hypobranchial eminence and so contribute to the formation of the epiglottis (p. 164). The adjoining portion becomes connected to the arytenoid swelling and may be identified in the aryepiglottic fold.

After the caudal portion of the hypobranchial eminence has been separated from the dorsal part of the tongue (p. 164), it is in continuity with two linear ridges which appear in the ventral wall of the pharynx, the whole forming an inverted U, regarded by His as an independent formation and called by him the *furcula*. Frazer identifies these vertical ridges as the sixth arches, placed very obliquely owing to the shortness of the pharyngeal floor compared with the greater extent of its roof. The contained groove of the furcula is carried downwards on the ventral wall of the fore-gut as the *laryngotracheal groove*, from which the lower part of the larynx, the trachea, bronchi and lungs are developed (p. 179). At the cephalic end of the groove paired arytenoid swellings arise which convert the slit-like upper aperture of the respiratory system into a T-shaped opening. The aryepiglottic folds can now be recognised extending from the arytenoid swellings to the epiglottis.

The **further development of the digestive tube.**—The portion of the fore-gut which succeeds the pharynx remains tubular, and is elongated to form the œsophagus. About the fourth week the stomach can be recognised as a fusiform dilatation (fig. 211), and beyond this the gut opens into the yolk-sac; this opening is at first wide, but is gradually narrowed into a tubular stalk (the *vitelline* or *vitello-intestinal duct*), which soon loses its connexion with the digestive tube (fig. 210). At this stage the stomach is placed in the median plane, and ventrally it is separated from the pericardium by the septum transversum (p. 72), which extends on to the cephalic side of the vitello-intestinal duct. Dorsally, the stomach is related to the dorsal aorta and, owing to the presence of the pleuroperitoneal canals on each side, it is connected to the body wall by a short dorsal mesentery, termed the *dorsal mesogastrium*. This mesentery is directly continuous with the dorsal mesentery of the gut. The liver develops as a hollow diverticulum from the ventral aspect of the fore-gut and grows headwards into the substance of the septum transversum (fig. 211), and it is this part of the latter which is sometimes termed the *ventral mesogastrium*.

In the human embryo, at the 10 mm. stage, the curvatures of the stomach are defined. Growth proceeds more actively along the dorsal border of the viscus; its convexity is notably increased and the rudiment of the fundus appears. As a result of the more rapid growth of the dorsal border the pyloric end of the stomach is carried ventrally and the concavity of the lesser curvature becomes apparent (fig. 210). At this stage the stomach presents right and left surfaces, to which the right and left vagus nerves are distributed.

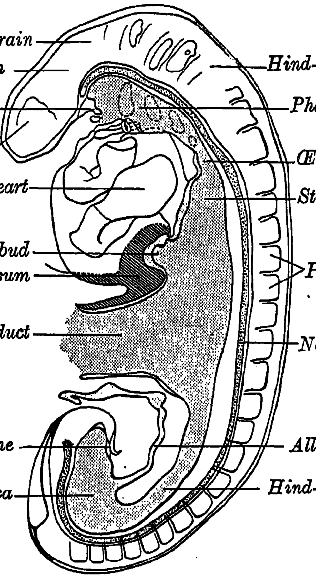
While these changes are occurring in the stomach, the gut increases in length more rapidly than the vertebral column, and forms a U-shaped loop, which acquires a dorsal mesentery as it lengthens, and projects into the cœlomic cavity (fig. 210). The rapidly growing liver and the developing mesonephroi encroach on the available space in the cœlom so much that the U-loop is extruded into the portion of the extra-embryonic cœlom which becomes included in the umbilical cord (p. 74). *This umbilical hernia is a normal condition in human embryos between the* 10 *mm.* (*sixth week*) *and the* 40 *mm. stage* (*third month*); under abnormal conditions it may be present at birth.

Partly as a result of the active growth of the fundus and the greater curvature, and partly influenced by the pressure exerted by the growing liver, the stomach becomes displaced to the left and rotated so that its right surface is directed dorsally and its left surface ventrally. In this way the omental bursa, which was hitherto a simple recess in the dorsal mesogastrium (p. 174), comes to lie dorsal to the stomach and may now be termed the *lesser sac* of the peritoneum.

The rotation of the stomach reacts on the position of the duodenum, which is also carried dorsally and to the right. At this stage the duodenum possesses a thick mesentery, which is continuous with the dorsal mesogastrium, on the one hand, and the mesentery of the U-loop, on the other (fig. 213). At a later

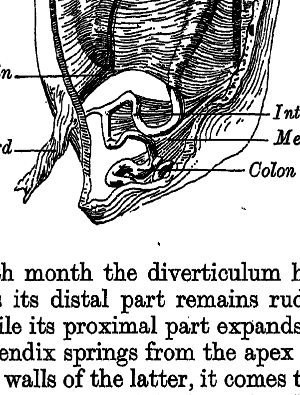
stage the approximation of the duodenum to the dorsal abdominal wall leads first to the adhesion of the right layer of its mesentery to the parietal peritoneum, and later to the absorption of both layers. In this way the duodenum comes to be retroperitoneal.

FIG. 211.—The digestive tube of a human embryo 2·5 mm. long. (Peter Thompson.)



At the 5 mm. stage a small diverticulum appears on the caudal limb of the U-loop (fig. 210) and is later differentiated into the cæcum and the vermiform appendix. Thereafter it is possible to distinguish the large from the small

FIG. 212.—The primitive mesentery of a human embryo. Half-schematic. (Kollmann.)

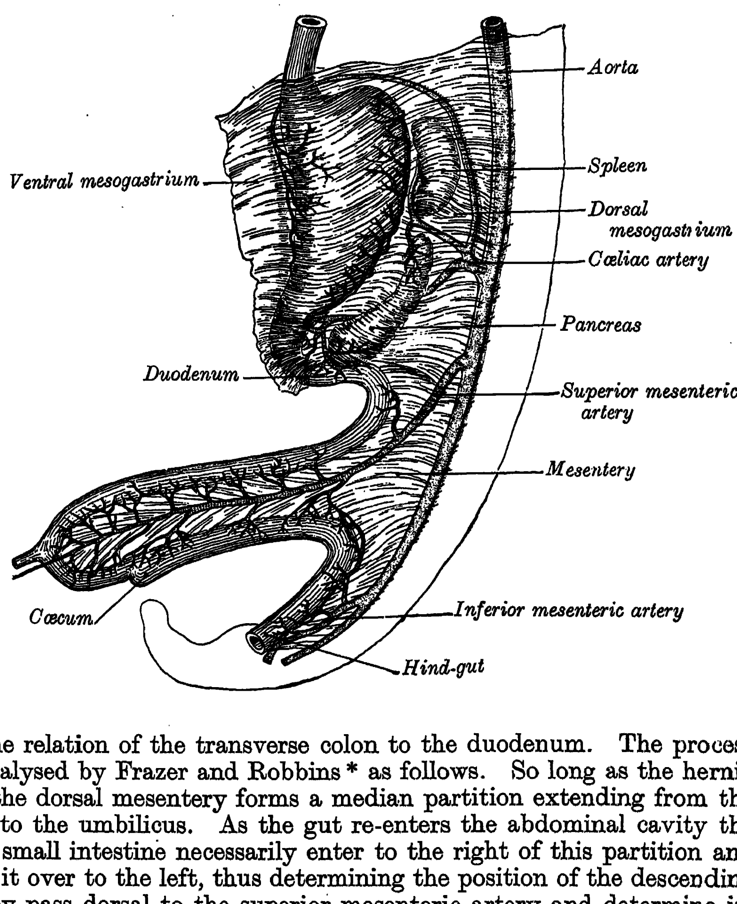


intestine. Until the fifth month the diverticulum has a conical outline, but from that time onwards its distal part remains rudimentary and forms the vermiform appendix, while its proximal part expands to form the cæcum. At birth the vermiform appendix springs from the apex of the cæcum, but, owing to unequal growth in the walls of the latter, it comes to open on its medial side.

When the U-loop enters the umbilical cord it has already been rotated

through an angle of 90°, so that the proximal limb lies to the right and the distal limb to the left (fig. 214). This relative position is maintained so long as the hernia persists, but during this period the portion which forms the small intestine becomes elongated and coiled, and the mesentery adapts itself to the changes in the gut. The colic part of the hernia elongates less rapidly and has no tendency to become coiled. By the time the embryo has attained a length of 40 mm. (middle of third month), the peritoneal cavity has enlarged sufficiently to contain all the abdominal viscera, and the hernia undergoes rapid reduction. The manner in which this occurs is important, for it is at this stage that the gut undergoes a process of *rotation,* which results in the establishment of the very constant relationships which the large intestine shows in the adult,

Fig. 213.—The abdominal part of the digestive tube and its attachment to the dorsal common mesentery. From a human embryo, six weeks old. (After Toldt.) (From Kollmann's Entwickelungsgeschichte.)



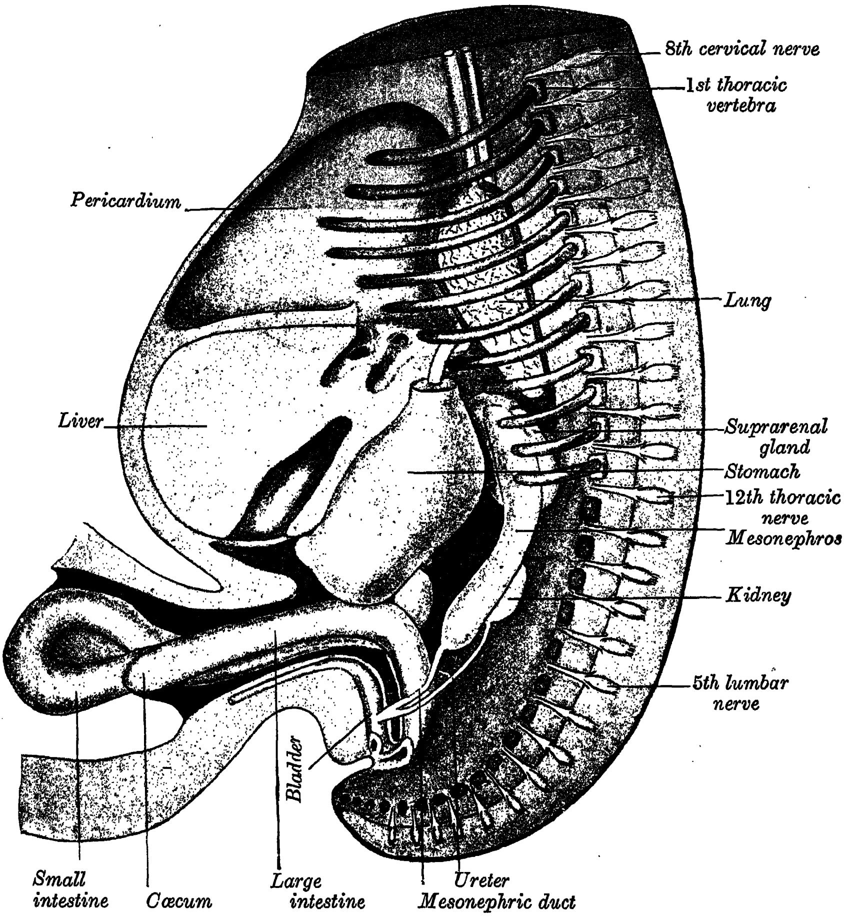
including the relation of the transverse colon to the duodenum. The process has been analysed by Frazer and Robbins * as follows. So long as the hernia is present, the dorsal mesentery forms a median partition extending from the dorsal wall to the umbilicus. As the gut re-enters the abdominal cavity the coils of the small intestine necessarily enter to the right of this partition and they thrust it over to the left, thus determining the position of the descending colon. They pass dorsal to the superior mesenteric artery and determine its adult relationship to the third part of the duodenum. The cæcum is the last part to re-enter the abdomen, and it lies at first on the surface of the coils of the ileum. The subsequent growth changes soon carry the cæcum dorsally and to the right, where it lies in contact with the caudal aspect of the liver. The portion of the colon which adjoins the cæcum now lies ventral to the duodenum and the rotation of the gut has been completed.

As a result of the manner in which the coils of small intestine re-enter the abdominal cavity the mesentery of the descending colon is thrust against the dorsal abdominal wall and the opposed peritoneal surfaces become adherent and are gradually absorbed. In this way the descending colon loses its mesentery and becomes retroperitoneal. Since this change takes place towards

* J. E. Frazer and R. H. Robbins, *Journal of Anatomy and Physiology,* vol. l.

the end of the third month the left colic vessels, whose position on the posterior abdominal wall is secondary, must lie in front of such structures as the left ureter and testicular or ovarian vessels, which are associated with the posterior wall originally. At the same time the proximal part of the colon is carried behind the lesser sac, and fusion takes place between the transverse mesocolon and the dorsal wall of the sac (fig. 215). During the later months of fœtal life the cæcum descends into the right iliac fossa, and the ascending colon so formed loses its mesentery in the same way and with the same results as happened in the case of the descending colon.

FIG. 214.—The trunk of a human embryo 17 mm. long. (After a reconstruction by Mall.) (From Quain's Elements of Anatomy, vol. i., Embryology.)

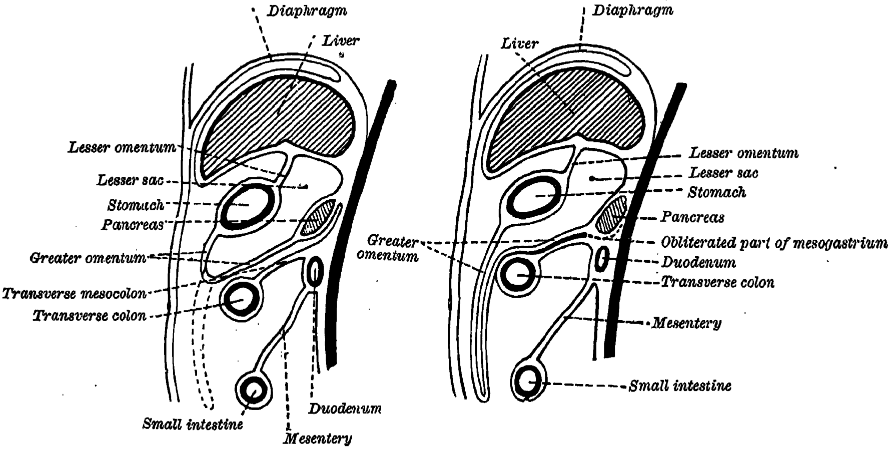


The rectum and anal canal.—With the formation of the tail-fold and the definition of the hind-gut (p. 71), the body-stalk is carried headwards on to the ventral surface of the body, and a bend is formed at the junction of the hind-gut and allantoic canal. Caudal to this bend the hind-gut dilates to form a pouch, which constitutes the *entodermal cloaca* ; into its dorsal part the hind-gut opens, and from its ventral part the allantoic canal passes into the body-stalk. At a later stage the mesonephric (Wolffian) and paramesonephric (Müllerian) ducts open into the ventral portion of the cloaca. Over the mid-ventral wall of the cloaca the entoderm comes into direct contact with the surface ectoderm without the interposition of mesoderm, and this area is termed the *cloacal membrane*. At first it extends on to the dorsal aspect of the body-stalk (fig. 96) but it undergoes real shortening (p. 71) and later the distance between it and the umbilicus gradually increases owing to the formation of the lower part of the abdominal wall. It should be noted that the cloacal membrane, in which the urogenital

and anal orifices subsequently develop, lies in the line of the primitive streak, which is carried round on to the ventral aspect of the body by the formation of the tail-fold. By the growth of the surrounding tissues the cloacal membrane comes to lie at the bottom of a depression, which is lined by ectoderm and named the *ectodermal cloaca* (fig. 216).

At the time when the mesonephric ducts enter the cloaca its ventral part is

FIG. 215.—Diagrams to illustrate the development of the greater omentum and the transverse mesocolon.



wider from side to side than its dorsal part, which remains very narrow. The mesoderm outside the line of union of these two parts grows rapidly and thrusts the entodermal epithelium inwards. As a result the two walls come into apposition and fuse. This process commences opposite the connexion of the allantoic canal with the cloaca and is continued caudally to form a septum, termed the *urorectal septum*, which separates the dorsal segment or rectum from the ventral segment which forms the urinary bladder and the urogenital sinus. At its

FIG. 216.—The tail-end of a human embryo, about four weeks old. (From a model by Keibel.)

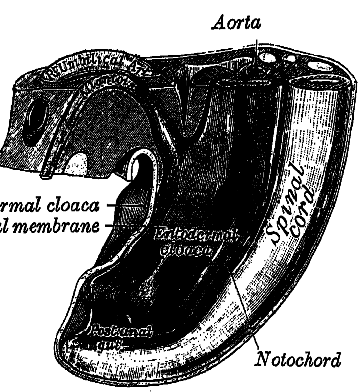
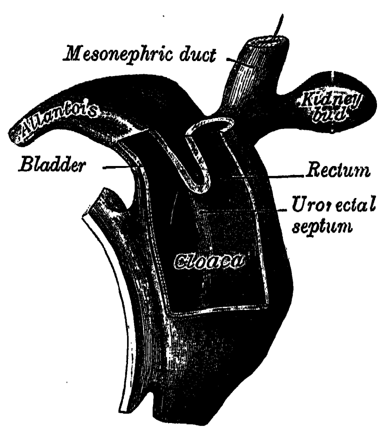


FIG. 217.—The cloaca of a human embryo, at the end of the fifth week. (From a model by Keibel.)

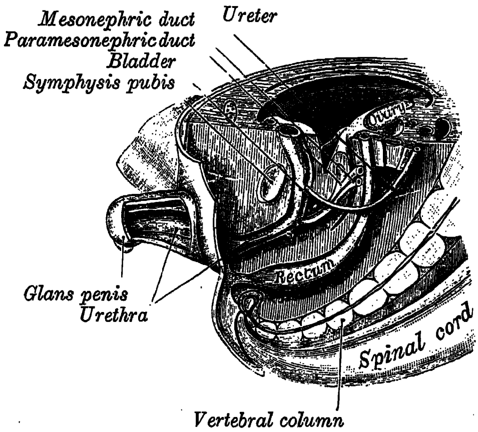


caudal end the urorectal septum reaches the cloacal membrane and divides it into an *anal* and *a urogenital membrane*. For a time a communication, named the *cloacal duct*, exists between the two parts of the cloaca caudal to the urorectal septum; this duct occasionally persists as a passage between the rectum and the bladder or urethra. By the upgrowth of anal tubercles * the anal part of the cloacal membrane comes to lie at the bottom of a depression, termed the

* Consult "Development of the anus in the human embryo," by Ellsworth M. Tench, *The American Journal of Anatomy*, vol. 59.

proctodœum. On the absorption and disappearance of this membrane the rectum communicates with the exterior (fig. 218). The lower part of the anal canal is formed from the proctodæum, but its upper part is entodermal in origin and is derived from the caudal end of the dorsal subdivision of the cloaca; the line of union corresponds with the edges of the anal valves in the adult. A small part of the hind-gut projects tailwards beyond the anal membrane; it is named the *post-anal gut* (fig. 210), and usually becomes obliterated and disappears.*

Fig. 218.—The tail-end of a human embryo, eight and a half to nine weeks old. (From a model by Keibel.)



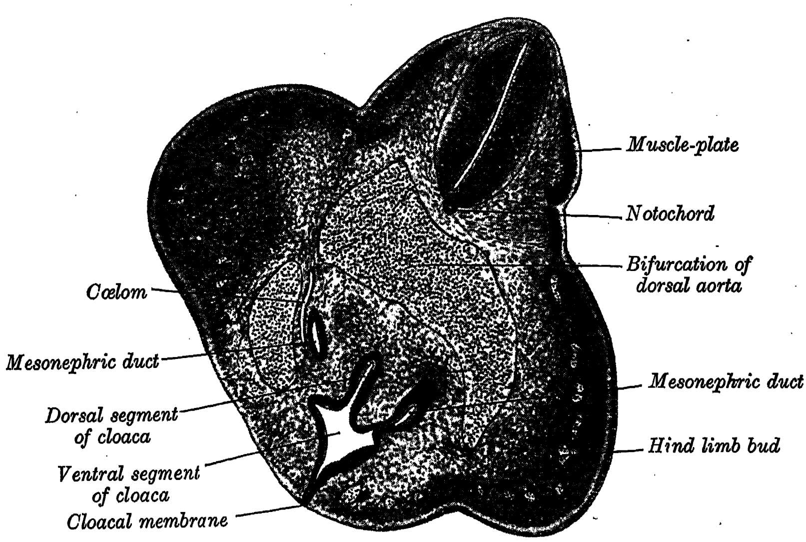
Applied Anatomy.—Abnormalities in the development of the digestive tube may lead to various disturbances which become apparent at birth or shortly after. Of these the following are the most common:

The closure of the laryngo-tracheal groove (p. 179) may be effected in such a way that the œsophagus is divided into two portions, viz. an upper, which communicates with the mouth above and ends blindly below in the neighbourhood of the tracheal bifurcation, and a lower, which communicates below with the stomach and above with the trachea.

Congenital stricture of the small intestine is usually due to exuberant overgrowth of the lining epithelium and the formation of adhesions. This overgrowth is a normal occurrence at one stage in the development of the duodenum, but the lumen is soon restored.

The umbilical hernia which is found between the 10 mm. and the 40 mm. stage (p. 168) may not be reduced and may be present at birth.

Fig. 219.—Oblique transverse section through a mole embryo, 5 mm. long, at the level of the bifurcation of the aorta. (Drawn from a microphotograph.)



The vitello-intestinal duct (p. 168) may remain patent as a constituent of the umbilical cord or its proximal part may persist as a "Meckel's diverticulum," which may or may not be anchored to the umbilicus by a fibrous band. In its simplest form a "Meckel's diverticulum" is a short, sac-like protrusion from the antimesenteric border of the ileum about three feet above the ileo-colic valve.

Rotation of the gut (p. 170) may fail to occur. In these cases the colon occupies the left,

* Consult in this connexion: "A Contribution to the Morphology of the Human Urogenital Tract," by D. Berry Hart, *Journal of Anatomy and Physiology,* vol. xxxv.

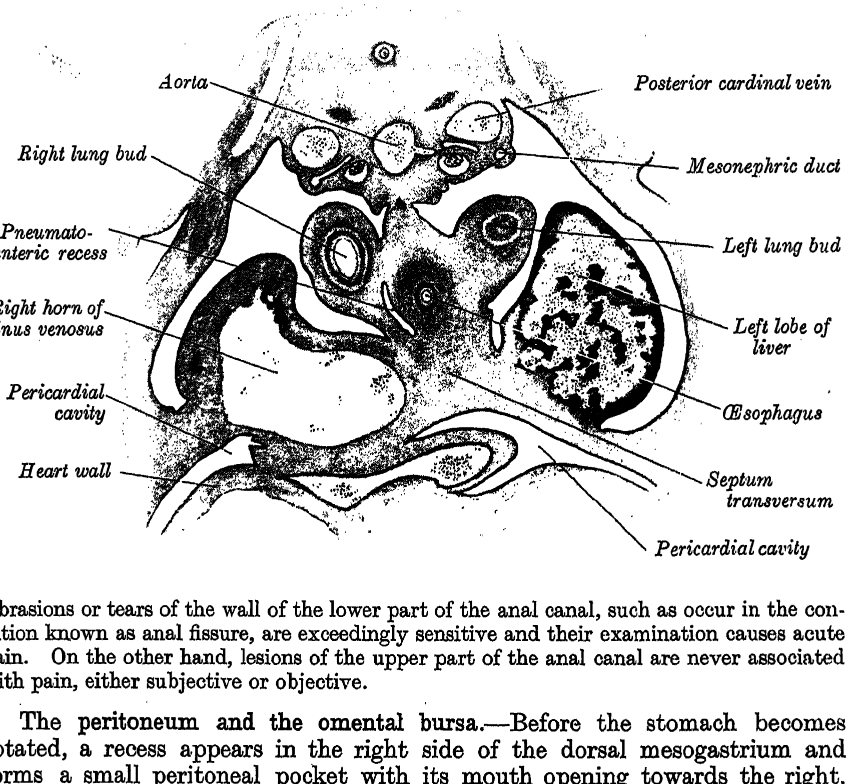
lower portion of the abdominal cavity and has no connexion with the greater omentum : the duodenum may be spirally coiled and the superior mesenteric vessels pass either behind it or to its left side.

The cæcum may retain its fœtal form with an apical vermiform appendix. It may fail to descend and is then found in front of the right kidney in close relation to the visceral surface of the liver. Occasionally it lies in the transverse mesocolon.

The separation of the entodermal cloaca into ventral and dorsal portions may be incomplete. The rectum then opens into the bladder, urethra or vagina and the anus is imperforate. The condition of imperforate anus may occur without other abnormalities. In some cases it is due to persistence of the anal membrane (p. 172) ; in others, the colon may end blindly, considerably above the level of the pelvic floor. The proctodæum may or may not be present.

On account of its mode of development the anal canal is lined in its lower part by modified skin, and in its upper part by mucous membrane which is entodermal in origin.

FIG. 220.—Transverse section of a human embryo 8 mm. long, showing the right pneumato-enteric recess. ×50.



Abrasions or tears of the wall of the lower part of the anal canal, such as occur in the condition known as anal fissure, are exceedingly sensitive and their examination causes acute pain. On the other hand, lesions of the upper part of the anal canal are never associated with pain, either subjective or objective.

The peritoneum and the omental bursa.—Before the stomach becomes rotated, a recess appears in the right side of the dorsal mesogastrium and forms a small peritoneal pocket with its mouth opening towards the right. This recess is termed the *bursa omentalis*, but it only corresponds to the inferior recess of the lesser sac of the adult. The recess does not involve the thick mesoduodenum, and its mouth extends from the œsophageal end of the stomach to the duodenum, occupying the position of the gastro-pancreatic folds of the adult.

A second, smaller recess appears at an early stage in the mesoderm covering the right side of the œsophagus (fig. 220). This is the *right pneumato-enteric recess*, and its mouth opens caudally, close to the mouth of the bursa omentalis. A similar recess develops on the left side, but it soon becomes closed and leaves no trace. The right pneumato-enteric recess becomes extended in a downward direction by the *hepato-enteric recess* which is formed during the growth of the right lobe of the liver (fig. 221). In its growth, the upper part of the right lobe of the liver invades the lower part of the right wall of the pneumato-enteric recess and then grows caudally along the line of the inferior vena cava (p. 155). A recess which is bounded ventrally by the caudate lobe of the liver is thus formed. It is continuous at its cephalic end with the right pneumato-enteric

recess and caudally it communicates with the cephalic part of the bursa omentalis. It is now possible to refer to a " lesser sac " and an " aditus to the lesser sac " (epiploic foramen) (fig. 222), although the caudal boundary of the

FIG. 221.—Transverse section through the same embryo as fig. 220, but 530μ more caudally. Note that rotation of the stomach has taken place and that the sinusoidal spaces in the liver communicate freely with one another. ×34.

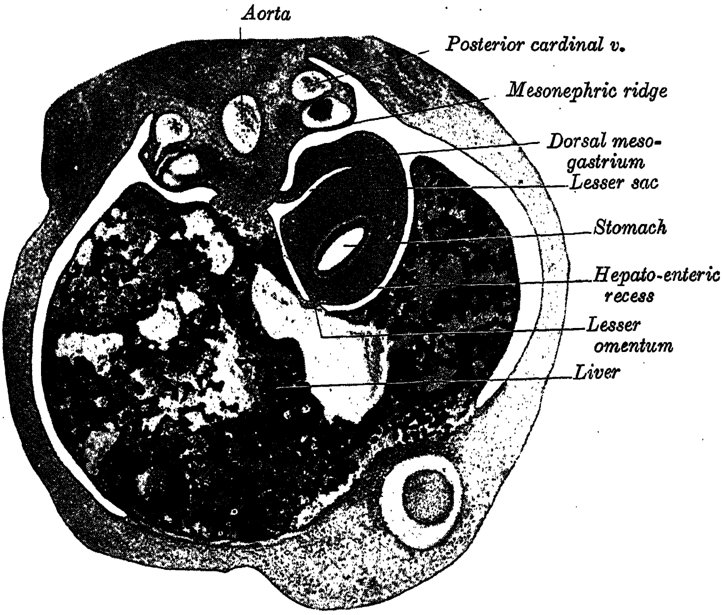
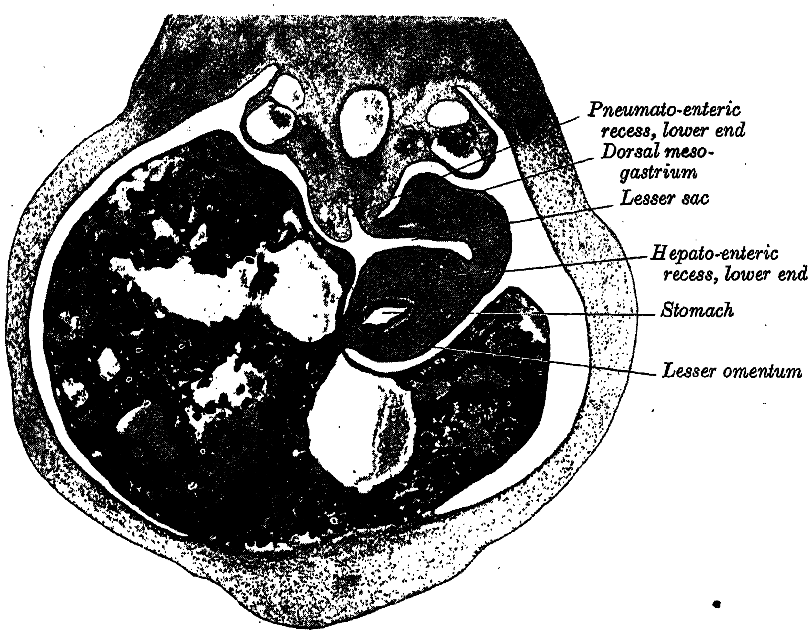


FIG. 222.—Transverse section through the same embryo as fig. 221, but 150μ more caudally. Observe that the " lesser sac " communicates with the general peritoneal cavity. ×34.



latter lacks definition until the mesoduodenum has disappeared. The cephalic part of the pneumato-enteric recess becomes cut off by the development of the diaphragm but sometimes remains as the *bursa infracardiaca*, a small serous

sac which lies medial to the basal part of the right lung, posterior to the inferior vena caval notch.

As the stomach enlarges the bursa omentalis keeps pace with it, and when

FIG. 223.—Diagram to show the fusion of the proximal part of the dorsal mesogastrium with the peritoneum on the posterior abdominal wall. Note also the conversion of the dorsal mesogastrium into the gastro-splenic and lieno-renal ligaments.

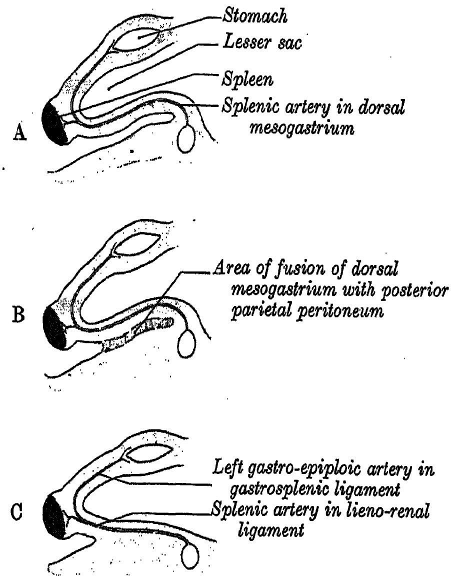
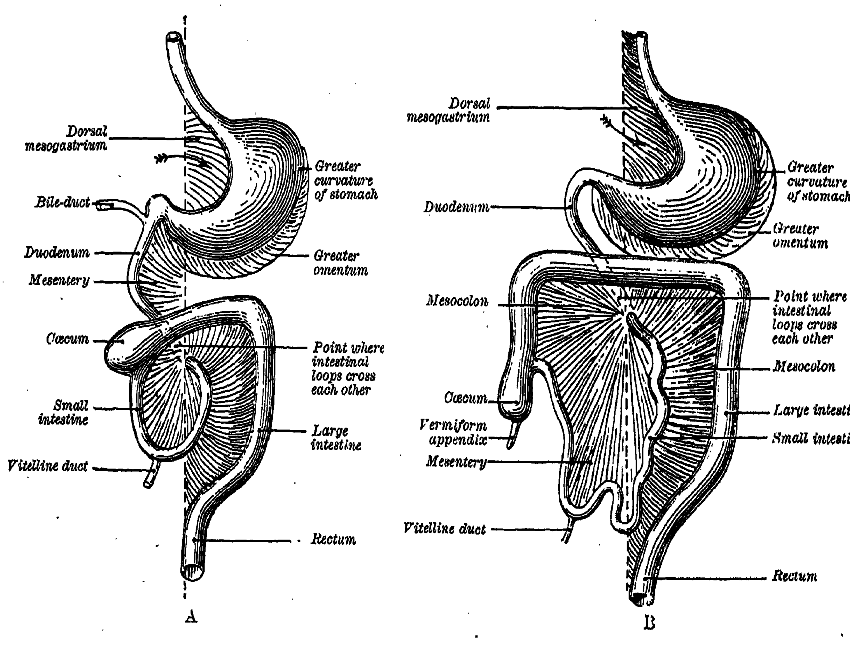


FIG. 224.—Diagrams to illustrate two stages in the development of the digestive tube and its mesentery. The arrow indicates the entrance to the bursa omentalis.



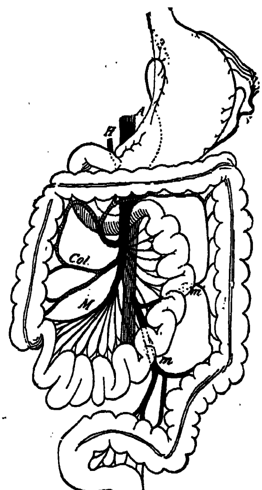
the intestines return to the abdominal cavity they come to lie caudal and dorsal to its caudal part. The dorsal wall of the cephalic part of the bursa becomes pressed against the dorsal abdominal wall and the opposed peritoneal layers fuse (fig. 223). Up to this time the dorsal mesogastrium has been attached in

the median plane, but as the result of the fusion the root of the mesogastrium acquires a new, curved attachment to the dorsal wall. From the œsophagus this attachment passes tailwards and to the left, giving the gastrophrenic and lienorenal ligaments of the adult, and then turns to the right and runs somewhat caudally and to the right along the line of the pancreas (fig. 215).

The development of the spleen in the cephalic part of the dorsal mesogastrium (p. 179) subdivides that part of it into a lienorenal and a gastroplenic ligament. The caudal part of the dorsal wall of the bursa remains free and grows caudally overlapping the transverse colon and the underlying coils of small intestine, forming the greater omentum. Later the two layers of the transverse mesocolon fuse with the overhanging dorsal surface of the greater omentum, so that the adult condition is attained (fig. 215).

The **liver** arises as a diverticulum from the ventral surface of the fore-gut at the point where the latter joins the vitelline duct (fig. 211). This diverticulum is lined with entoderm, and grows ventrally and headwards into the septum transversum, giving off two solid buds of cells, which represent the right and the left lobes of the liver. The solid buds of cells grow into columns or cylinders, termed the *hepatic cylinders*, which branch and anastomose to form a close meshwork. This network invades the vitelline and umbilical veins, and breaks them up into a series of capillary-like vessels termed *sinusoids* (Minot), which ramify in the meshes of the cellular network (fig. 221). By the continued growth and ramification of the hepatic cylinders the mass of the liver is gradually formed, but its connective tissue stroma is derived from included mesenchymal cells of the septum transversum. The original diverticulum from the duodenum forms the bile duct, and from its distal part the cystic duct and gall bladder arise as a solid outgrowth which later acquires a lumen. The opening of the bile duct is at first in the ventral wall of the duodenum; later, it is carried to the left across the dorsal (originally right) surface of the duodenum to the position which it occupies in the adult on the medial (or mesenteric) border. This migration of the orifice is effected by differences in the rate of growth in different parts of the walls of the duodenum.

FIG. 225.—The final disposition of the intestines and their vascular relations. (Jonnesco.)



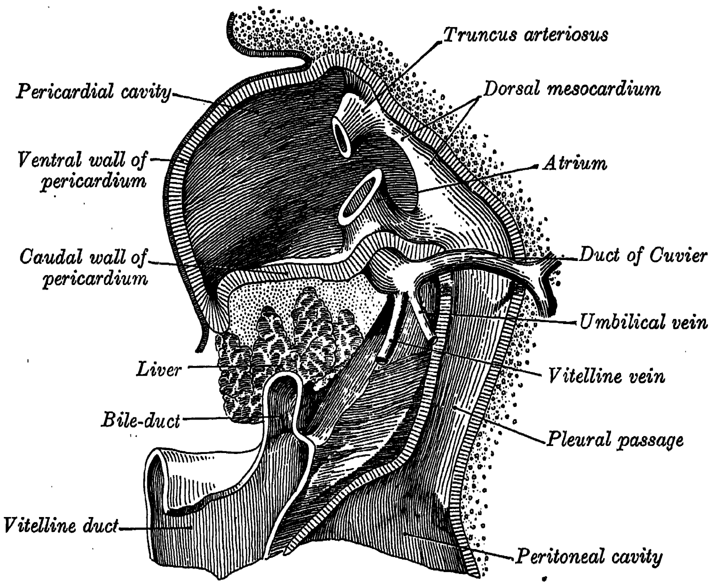
A, Aorta. *H*, Hepatic artery. *M*, *Col.* Branches of superior mesenteric artery. *m*, *m′*. Branches of inferior mesenteric artery. *S.* Lienal artery.

As the liver undergoes enlargement, both it and the ventral mesogastrium are gradually differentiated from the septum transversum; and from the caudal surface of the latter the liver projects tailwards into the abdominal cavity. By the growth of the liver the ventral mesogastrium is divided into two parts, of which the ventral forms the falciform and coronary ligaments and the dorsal the lesser omentum. About the third month the liver almost fills the abdominal cavity, and its left lobe is nearly as large as its right. From this period the relative development of the liver is less active, more especially that of the left lobe, which actually undergoes some degeneration and becomes smaller than the right; but up to the end of fœtal life the liver remains relatively larger than in the adult.

The **pancreas** (figs. 227, 228).—The pancreas is developed in two parts, a dorsal and a ventral. The former arises as a diverticulum from the dorsal wall of the duodenum a short distance headwards of the hepatic diverticulum, and, growing headwards and dorsally in the mesoduodenum, enters that part of the dorsal mesogastrium which is forming the dorsal wall of the bursa omentalis. It forms the whole of the neck, body and tail of the pancreas and a part of the head. The ventral part appears in the form of a diverticulum from the primitive bile duct at the spot where the latter opens into the duodenum.

This diverticulum is at first double, but the two outgrowths soon fuse, and the diverticulum, now a single mass, grows round the gut into the mesoduodenum, where it enlarges to form the remainder of the head of the gland.* The duct of the dorsal part (accessory pancreatic duct) therefore opens directly into the duodenum, while that of the ventral part (pancreatic duct) opens with the bile duct. About the seventh week the two parts of the pancreas meet and

FIG. 226.—The liver with the septum transversum. Human embryo, 3 mm. long. (After a model and figure by His.)



fuse, and a communication is established between their ducts. After this has occurred the terminal part of the accessory duct, i.e. the part between the duodenum and the point of meeting of the two ducts, undergoes little or no enlargement, while the duct of the ventral part increases in size and forms the main duct of the gland. The opening of the accessory duct into the

FIG. 227.—The pancreas of a human embryo, six weeks old. (Kollmann.)

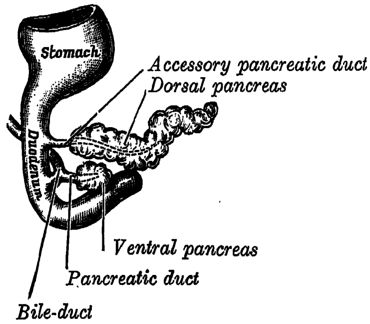
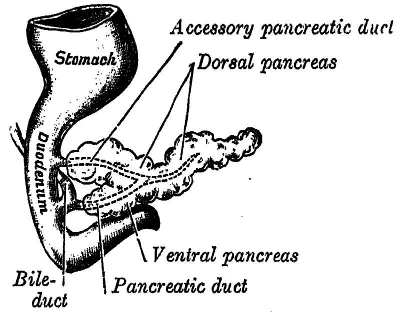


FIG. 228.—The pancreas of a human embryo, at the end of the seventh week. (Kollmann.)



duodenum is sometimes obliterated, and, even when it remains patent, it is probable that the whole of the pancreatic secretion is conveyed through the main duct.

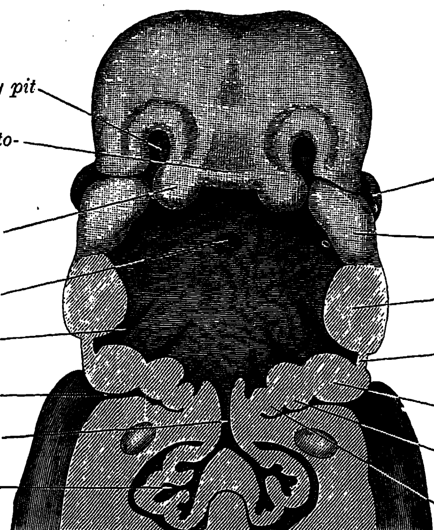
At first the body of the pancreas is directed headwards and dorsally between the two layers of the dorsal mesogastrium, in the dorsal wall of the bursa omentalis. When this wall fuses with the dorsal parietal peritoneum the

* P. N. B. Odgers, *Journal of Anatomy*, vol. lxv. October, 1930.

process extends tailwards as far as the caudal (inferior) border of the pancreas, and thus, in the adult, the gland becomes retroperitoneal.

The spleen (fig. 213).—Although the spleen belongs to the group of ductless glands, its development may be conveniently referred to here. It appears about the sixth week as a localised thickening of the cœlomic epithelium of the dorsal mesogastrium in its cephalic portion, and the proliferating cells invade the underlying mesenchyme, which has become condensed and vascularised. The process occurs simultaneously in several adjoining areas which soon fuse to form a lobulated spleen, derived in part from the cœlomic epithelium and in part from the mesenchyme in the dorsal mesogastrium. As the organ enlarges it projects to the left, so that its surfaces come to be covered with the peritoneum of the greater sac. When fusion occurs between the dorsal wall of the lesser

FIG. 229.—The head and neck of a human embryo in the sixth week. Ventral aspect. The floor of the mouth and the ventral wall of the pharynx have been removed. (His.)



sac and the dorsal parietal peritoneum, the process does not extend so far to the left as the spleen (fig. 223), which remains connected to the dorsal abdominal wall by a short lienorenal ligament, while its primitive connexion with the stomach forms the gastrosplenic ligament. The earlier lobulated character of the organ disappears but is indicated by the presence of notches on its upper border in the adult.

The respiratory organs.—The rudiment of the respiratory organs appears in the fifth week as a median *laryngo-tracheal groove* in the ventral wall of the pharynx. The groove deepens and its lips fuse to form a septum, which converts the groove into a tube, termed the *laryngo-tracheal tube* (fig. 229), which opens into the pharynx by a slit-like aperture formed by the edges of the persistent cephalic part of the groove. The process of fusion commences at the caudal end of the groove and extends headwards. The tube is lined with entoderm, and from this the epithelial lining of the respiratory tract is developed. The cephalic part of the tube forms the larynx, and its next succeeding part the trachea, while from its caudal end two lateral outgrowths arise and form the right and left *lung-buds*. The latter are surrounded by mesenchyme, from which the connective tissue of the bronchi and lungs is developed.

The first rudiment of the larynx consists of the cephalic end of the laryngo-tracheal groove, bounded ventrally by the caudal part of the hypobranchial eminence (p. 164) and on each side by the ventral ends of the sixth arch (Frazer). Two arytenoid swellings appear, one on each side of the groove, and, as they enlarge, they become approximated to each other, and to the caudal part

of the hypobranchial eminence, from which the epiglottis is developed. The upper aperture of the larynx is at first a vertical slit, which is converted into a T-shaped cleft by the enlargement of the arytenoid swellings; the vertical limb of the T lies between the two arytenoid swellings and its horizontal limb between them and the epiglottis. Soon after its appearance the epithelial walls of the cleft adhere to each other, and the aperture of the larynx remains occluded until the third month, when its lumen is regained. The upgrowth of the arytenoid swellings and the deepening of the primitive aryepiglottic folds form the walls of the vestibule and leave its aperture above the level of the primitive aperture, which now corresponds to the level of the glottis. The arytenoid swellings are differentiated into the arytenoid and corniculate cartilages, and the folds joining them to the epiglottis form the aryepiglottic folds in which the cuneiform cartilages are developed as derivatives of the epiglottis. The thyroid cartilage is developed from the ventral ends of the

Fig. 230.—The lung-buds from a human embryo, about five weeks old, showing commencing lobulation. (His.)

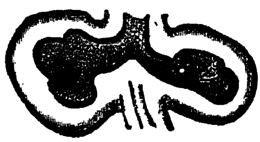
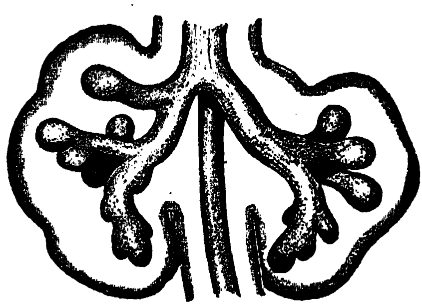


Fig. 231.—The lungs of a human embryo more advanced in development. (His.)



cartilages of the fourth and fifth branchial arches; it appears as two lateral plates, each chondrified from two centres and united in the midventral line by membrane in which an additional centre of chondrification develops. The cricoid cartilage arises from two cartilaginous centres, which soon unite ventrally and gradually extend and ultimately fuse on the dorsal surface of the tube.*

The right and left lung-buds make their appearance before the laryngotracheal groove is converted into a tube. They grow out caudal to the ducts of Cuvier, and divide into lobules, three appearing on the right, and two on the left, lung-bud; these subdivisions are the early indications of the corresponding lobes of the lungs (figs. 230, 231). The buds undergo further subdivision and ramification, and ultimately end in minute expanded extremities—the infundibula of the lung. After the sixth month the air-sacs begin to make their appearance on the infundibula in the form of minute pouches. The pulmonary arteries are derived from the sixth aortic arches. During the course of their development the lungs migrate in a caudal direction, so that by the time of birth the bifurcation of the trachea is opposite the fourth thoracic vertebra. As the lungs grow they project into the pleural passages, or parts of the cœlom which will ultimately form the pleural sacs, and the splanchnic mesoderm enveloping the lung rudiment expands on the growing lung and is converted into the pulmonary pleura.

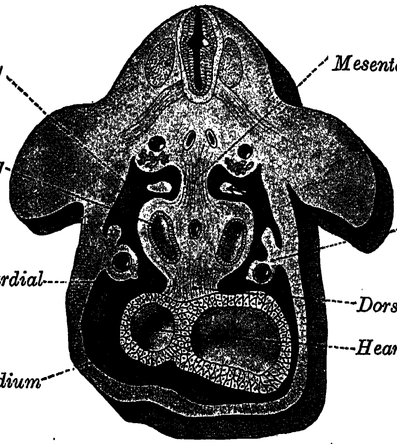
THE DEVELOPMENT OF THE BODY-CAVITIES

The appearance of the intra-embryonic cœlom and the manner in which it communicates with the extra-embryonic cœlom have already been described (p. 66). Prior to the formation of the head-fold the pericardium lies at the headward end of the embryonic area and communicates caudally, on each side of the median plane, with the rest of the cœlom. After the formation of the

* E. Fawcett, *loc. cit.*

head-fold the pericardium communicates dorsally with the pleural passages by means of two pleuropericardial canals (fig. 226); and the pleural passages open caudally into the peritoneal cavity. The duct of Cuvier crosses the lateral aspect of the pleuropericardial canal, as it passes ventrally to reach the sinus venosus, which is imbedded in the septum transversum (p. 136).

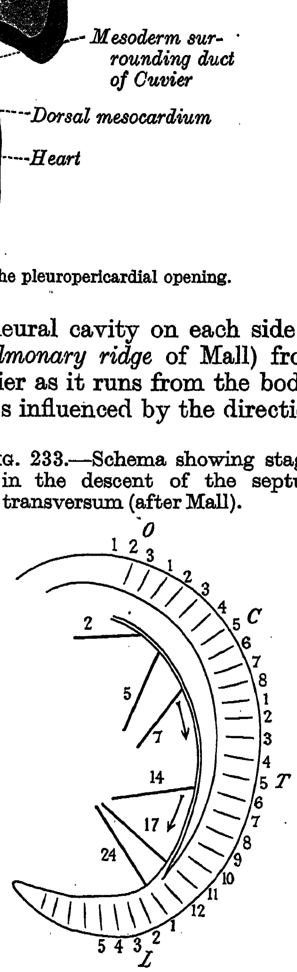
FIG. 232.—A transverse segment through the upper part of the cœlom of a human embryo, 7·5 mm. long. (Kollmann.)



The upper arrow is in the pleuroperitoneal, the lower in the pleuropericardial opening.

The separation of the pericardial from the pleural cavity on each side is effected by the growth of a ridge of tissue (*pulmonary ridge* of Mall) from the mesenchyme associated with the duct of Cuvier as it runs from the body-wall to the septum transversum, but the process is influenced by the direction in which the developing lung-buds enlarge. They project at first into the pleural passage, but, as growth proceeds, they extend in a lateral direction, *caudal to the ducts of Cuvier* and the pulmonary ridges. As the apical part of the lung forms, it does not grow headwards in the pleural passage but invades the body-wall and ascends *on the lateral aspect of the duct of Cuvier.* The pleuropericardial canal still lies medial to the vessel, which intervenes between it and the developing apical part of the pleural sac. It is reduced to a narrow slit, which is soon obliterated by the apposition of its walls (fig. 183).

FIG. 233.—Schema showing stages in the descent of the septum transversum (after Mall).



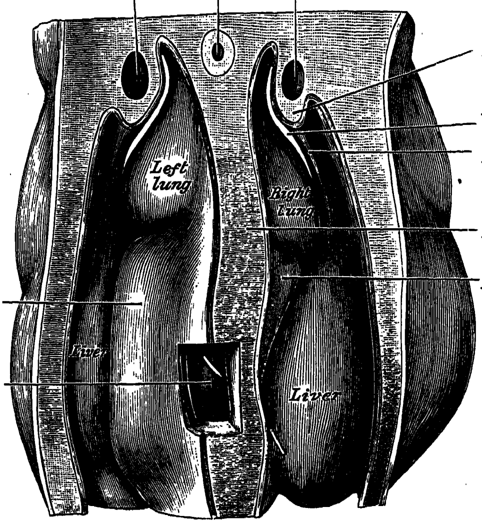
The numerals on the heavy lines indicate the length of the embryo in mm., and the position of the occipital, cervical, thoracic and lumbar segments is also shown.

In addition to its extension in a headward direction the lung enlarges ventrally and medially, and the pleura is therefore carried into the body-wall over the surface of the pericardium, thus separating it from the lateral thoracic walls (fig. 235).

The separation of the pleural and peritoneal cavities from each other is effected on each side by the formation of a *pleuro-peritoneal fold* or *membrane.* This fold is commonly described as an active ingrowth from the body-wall, but it may be attributed to the influences exerted by the growing lung-bud and the growing liver. As the latter enlarges, it projects into the peritoneal cavity and acquires, on each side of its connexion with the septum transversum, a cephalic peritoneal-covered surface. At the same time the body-wall is growing rapidly in order to provide the increase in the diameters of the trunk rendered

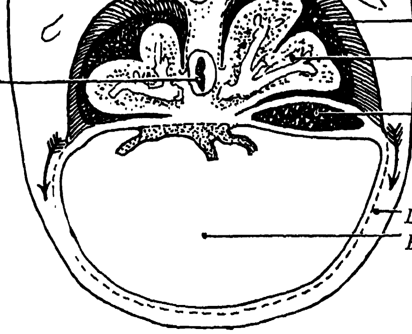
necessary by the growth of the liver. Just as the enlargements of the lung headwards and ventrally were effected by a process of burrowing into the body-wall, so its caudal enlargement is effected in the same way. The expanding and

Fig. 234.—The upper part of the cœlom of a human embryo of 6·8 mm. long. Dorsal aspect. (From a model by Piper.)



elongating lung-base grows into the body-wall and its peripheral part becomes separated from the peritoneal-covered right (or left) lobe of the liver by a crescentic fold of body-wall, which constitutes the pleuroperitoneal fold or membrane. On each side the free, inner edge of this fold forms the dorsilateral

Fig. 235.—A diagram of a transverse section through a rabbit embryo. (After Keith.)

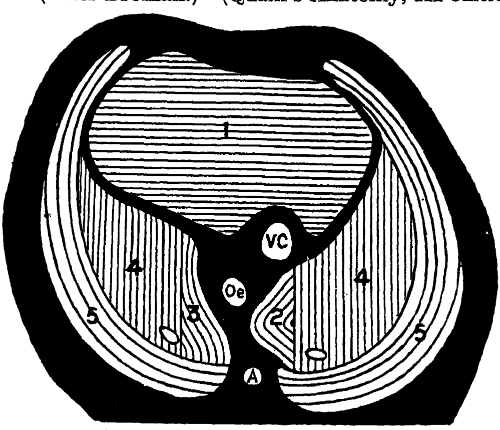


boundary of the communication between the pleural sac and the peritoneal cavity, the other boundaries being formed by the dorsilateral part of the septum transversum and the lateral aspect of the dorsal mesentery of the caudal end

of the œsophagus. On the right side the mass of the right lobe of the liver blocks the communication and renders easy the approximation of the boundaries of the opening. Closure therefore occurs earlier on the right than on the left side, where the position is complicated by the fact that the left lobe of the liver is smaller, and the left suprarenal gland, which projects at first into the caudal part of the left pleural sac dorsimedially, occupies the rest of the gap. It is therefore on the left side that an abnormal communication between the pleural and the peritoneal cavities most frequently is found. The further development of the peritoneal cavity has already been described (p. 174).

While these changes are in progress, the septum transversum undergoes a progressive alteration in position. In a human embryo, 2 mm. long, the dorsal border of the septum transversum lies opposite the second cervical segment, but as the embryo grows, and the heart enlarges, it migrates in a caudal direc-

FIG. 236.—Diagram to show the elements which contribute to the formation of the diaphragm. (After Broman.) (Quain's Anatomy, XI edition, vol. i.)



1, part derived from septum transversum ; 2 and 3, parts derived from the dorsal mesentery ; 4, parts derived from the pleuroperitoneal membranes ; 5, parts derived from the body-wall.

tion. At first the ventral border moves more rapidly than the dorsal border, but after the embryo has attained a length of 5 mm. it is the dorsal border which migrates more rapidly (fig. 233). When the dorsal border of the septum transversum lies opposite the fourth cervical segment, the phrenic nerve (*C* 3, 4 and 5) and portions of the corresponding myotomes grow into it and accompany it in its later migrations. It is not until the end of the second month that the dorsal border of the septum transversum comes to lie opposite the last thoracic and first lumbar segments, the position which is occupied by its derivative, the diaphragm, in the adult.

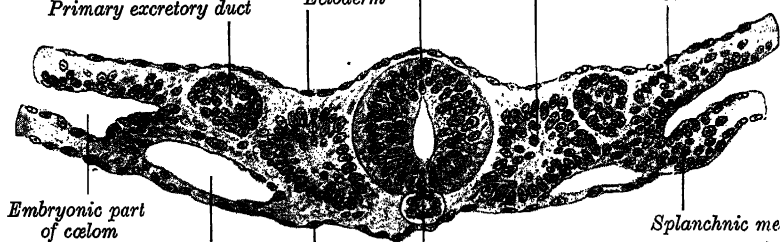
The development of the diaphragm.—The closure of the pleuroperitoneal openings completes a mesodermal partition which separates the thoracic from the abdominal viscera and occupies the position of the diaphragm in the adult. This partition has a composite origin ; its ventral and median portion is derived from the septum transversum, its dorsal portion from the dorsal mesentery, and its dorsilateral portions from the pleuroperitoneal folds. According to Broman the lateral body-wall makes a mesodermal contribution to the partition along the outer margins of the pleuroperitoneal folds and the septum transversum. Premuscle tissue, derived principally from the fourth cervical myotome, invades the septum transversum as already described and from this position extends into the rest of the partition, giving rise to the muscular diaphragm (fig. 236).

THE DEVELOPMENT OF THE UROGENITAL ORGANS

The excretory and reproductive organs are developed from the mesoderm of the intermediate cell-mass (p. 65) and they are intimately associated with

one another, especially in the earlier stages of their development. The excretory organs are noteworthy in that three distinct sets of them appear in the course of development, viz.: the pronephros, the mesonephros and the metanephros. The pronephros disappears entirely, but its duct persists and becomes the duct of the mesonephros. Most of the mesonephros undergoes degenerative changes and disappears, but some of its tubules play an important part in connexion

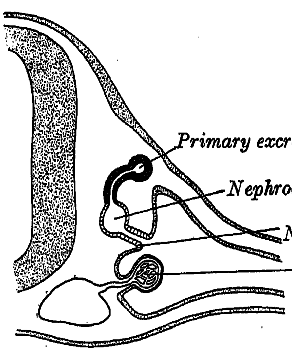
FIG. 237.—A transverse section through a ferret embryo. (A. Robinson.)



with the male sexual gland. The metanephros is the last to appear, and it persists as the permanent kidney.

The **pronephros** is a very rudimentary and transient organ in the human embryo; it begins to appear in embryos of 1·7 mm. length and, as a rule, with the exception of its duct, no trace is left by the time the embryo has attained a length of 5 mm. It is found in the intermediate cell-mass of the seventh to the fourteenth segments (lower cervical and upper thoracic regions) and consists of six or seven horizontal tubules, which usually show a distinctly segmental character. The tubules open into the dorsal part of the cœlom by means of *nephrostome canals*, while their originally blind ends turn caudally and link up with one another to form a longitudinal duct, termed the pronephric or *primary excretory duct*. Medial to the opening of the nephrostome canal the cœlomic epithelium shows a small tuft-like protrusion into which the aorta sends one of its lateral branches, converting it into an *external glomerulus* (fig. 238). A typical pronephric tubule shows a localised dilatation, termed the *nephrocoele*, into which, in some animals though not in man, internal glomeruli project.

FIG. 238.—Diagram of a pronephric segment. (After Felix.)

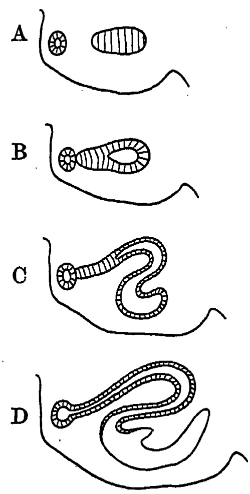


The primary excretory duct lies immediately under the surface ectoderm and grows tailwards, curving ventrally to reach the side of the entodermal cloaca, into which it opens in 4·3 mm. embryos. Caudal to the tenth segment the duct grows tailwards more rapidly than the process of segmentation. The mesoderm into which it extends is in line with the intermediate cell-mass and forms an unsegmented column, termed the *nephrogenic cord*.

The **mesonephros (Wolffian body)**, which succeeds the pronephros, differs from it in two important particulars; (*a*) such nephrostomes as may develop are few in number and transitory, and they never establish connexions with the mesonephric tubules; (*b*) the glomeruli are all *internal* and secrete directly into the tubules.

The mesonephros extends from the sixth cervical segment to the third lumbar so that its cephalic end overlaps the caudal end of the pronephros. The organ occupies the greater part of the nephrogenic cord, lying medial to the primary excretory duct. It consists of about seventy to eighty tubules and a corresponding number of internal glomeruli, which are not segmental in their arrangement. All of these tubules, however, are not present at the same time, and it is rare to find more than thirty to forty in any individual embryo, for the cephalic tubules and glomeruli atrophy and disappear before the development of those which are situated more caudally. Each tubule first appears as a solid mass of cells, which later becomes hollowed in the centre (fig. 239); one end grows towards and finally opens into the primary excretory duct, which thus becomes the *mesonephric* (Wolffian) *duct*, while the other end becomes dilated and is invaginated by a tuft of vessels derived from a lateral branch of the aorta, the whole constituting an *internal glomerulus*. By the end of the sixth week the mesonephros forms an elongated, spindle-shaped organ, which projects into the cœlomic cavity on each side of the dorsal mesentery, from the septum transversum to the third lumbar segment. This projection is termed the *mesonephric* (Wolffian) *ridge* (fig. 221), and the genital glands are developed on its medial surface.

FIG. 239.—Diagram showing stages in the development of the tubules and Malpighian corpuscles of the mesonephros. (After Felix.)



In *A* the tubule is a solid epithelial mass having no connexion with the primary excretory duct. In *B* it has acquired a lumen and is in contact with the duct. In *D* it has opened into the duct, while its opposite extremity has been invaginated by a vascular tuft (not shown in the diagram) and has been converted into a Malpighian corpuscle.

In fishes and amphibians the mesonephros persists and forms the permanent kidney, but in reptiles, birds and mammals it is replaced, as the principal excretory organ, by the metanephros. In both sexes the cephalic end of the mesonephros atrophies and disappears, and in embryos of 20 mm. length the organ is found only in the first three lumbar segments, although it may still possess as many as twenty-six tubules. Of these tubules the cephalic six to twelve persist to form the *efferent ducts of the testis*, in the male, and the tubules of the *epoöphoron* in the female; the caudal tubules form the *ductus aberrans* and the *paradidymis*, in the male, and the *paroöphoron*, in the female.

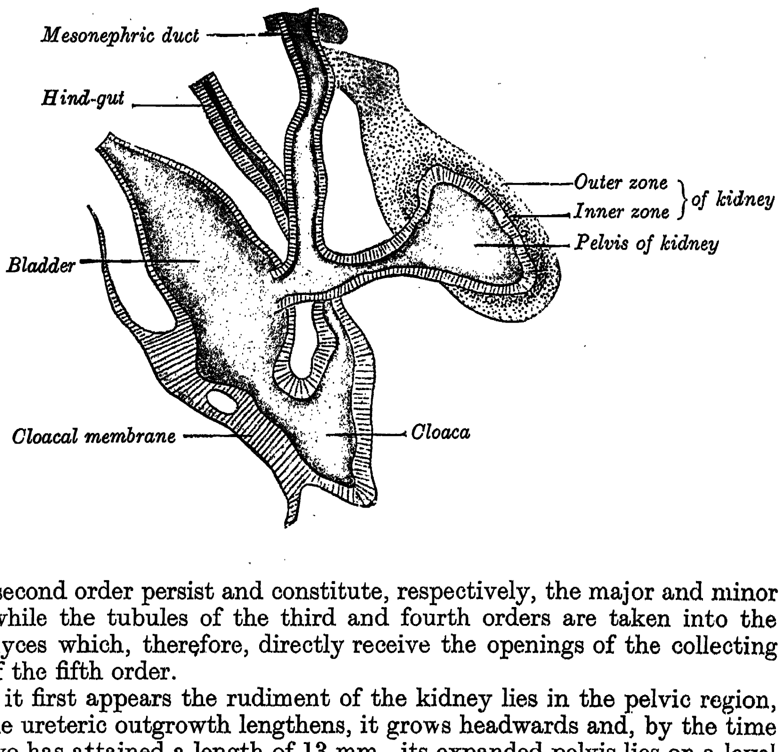
The *mesonephric duct* runs tailwards in the lateral part of the mesonephric ridge and, at the caudal end of the mesonephros, is projected into the cavity of the cœlom in the free border of a mesodermal fold (fig. 241). As the ducts approach the urogenital sinus the two folds fuse with each other, between the bladder ventrally, and the rectum, dorsally, forming a transverse partition across the cavity of the pelvis which is termed the *genital cord* (fig. 242). In the male the peritoneal fossa between the bladder and the genital cord becomes obliterated, but it persists in the female as the uterovesical pouch. The mesonephric duct itself becomes the canal of the epididymis, the vas deferens (ductus deferens) and the ejaculatory duct in the male, and it later gives rise to a diverticulum which forms the seminal vesicle. In the female it constitutes the horizontal duct of the epoöphoron.

The **metanephros**, or permanent kidney, has a twofold origin. At about the 5 mm. stage an outgrowth forms from the dorsal and medial aspect of the mesonephric duct, near the point at which it opens into the cloaca. This outgrowth is the *ureteric diverticulum*, and it travels dorsally at first and then inclines headwards. Its blind extremity, which grows into the caudal end of the nephrogenic cord, becomes expanded and the adjoining mesoderm condenses around it to form the *metanephrogenic cap* (fig. 240). The stalk of the ureteric diverticulum becomes the ureter, and its expanded end gives origin not only

to the pelvis of the ureter and the calyces but also to the collecting tubules of the kidney. The secreting and convoluted tubules and the renal corpuscles are all derived from the metanephrogenic cap. As a result, the blind ends of the secreting tubules must establish communication with the blind ends of the collecting tubules; should they fail to do so, congenital cysts of the kidney will be formed.

The expanded extremity of the ureter gives origin to four collecting tubules of the first order and itself forms the primitive renal pelvis. Each of these tubules ends in an ampullated extremity, which gives rise to collecting tubules of the second order. These, in turn, give rise to collecting tubules of the third order, and so on. In some animals the four collecting tubules of the first order are taken into the renal pelvis, which then presents a single renal papilla and no subdivision into calyces. In man, however, the collecting tubules of the

FIG. 240.—The primitive kidney and the bladder, from a reconstruction. (After Schreiner.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



first and second order persist and constitute, respectively, the major and minor calyces, while the tubules of the third and fourth orders are taken into the minor calyces which, therefore, directly receive the openings of the collecting tubules of the fifth order.

When it first appears the rudiment of the kidney lies in the pelvic region, but, as the ureteric outgrowth lengthens, it grows headwards and, by the time the embryo has attained a length of 13 mm., its expanded pelvis lies on a level with the second lumbar vertebra. During this period the developing kidney receives its blood-supply from arteries in its immediate neighbourhood, the middle sacral and common iliac arteries, but the definitive renal artery is not recognisable until the beginning of the third month. It arises from the most caudal of the three suprarenal arteries, all of which represent persistent mesonephric or lateral splanchnic arteries (p. 150). Additional renal arteries are by no means uncommon. They may enter at the hilum or at the upper or lower pole of the gland, and they also represent persistent mesonephric arteries.

At an early stage the kidney is a lobulated organ, a condition which persists throughout fœtal life and only disappears after birth.

The ureter undergoes little alteration, save that it grows in length in conformity with the embryo. Two fusiform enlargements appear subsequently, one affecting its lumbar and the other its pelvic portion. The lumbar enlargement appears during the fifth month, but the pelvic enlargement does not develop until the ninth month and is not constant. As a result the ureter

shows a constriction at its upper end and another as it crosses the brim of the pelvis. A third constriction is always present at its lower end, and is caused by the growth of the bladder wall.

At first the ureter is connected to the dorsal and medial aspect of the

FIG. 241.—Transverse section through the lower abdomen of a human embryo, nine weeks old, to show the connexions and relative positions of the structures derived from the Wolffian ridge.

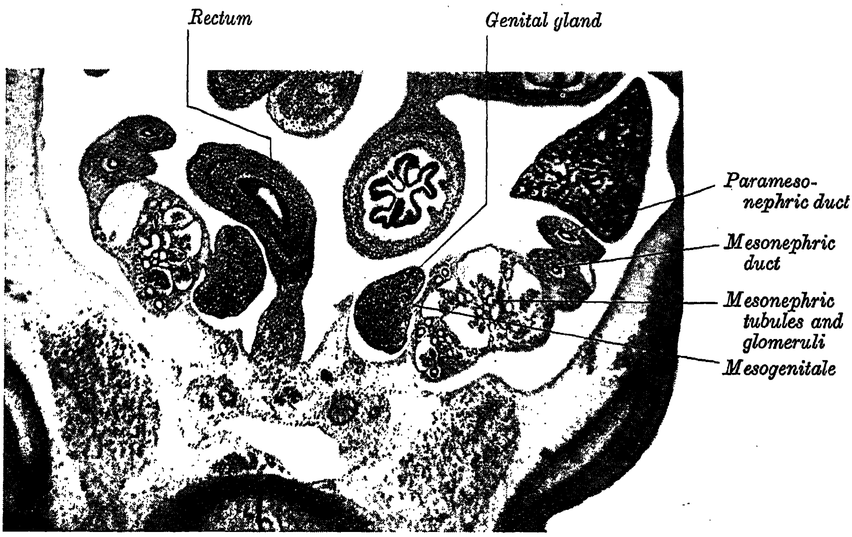
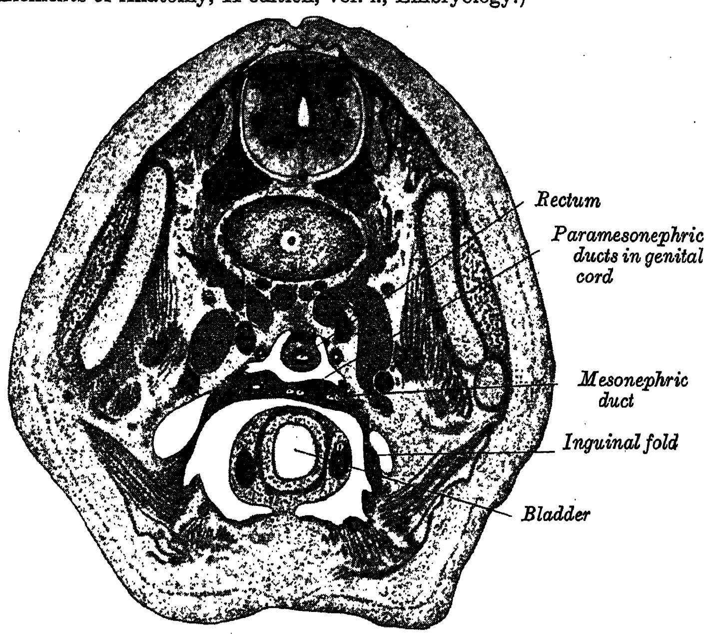


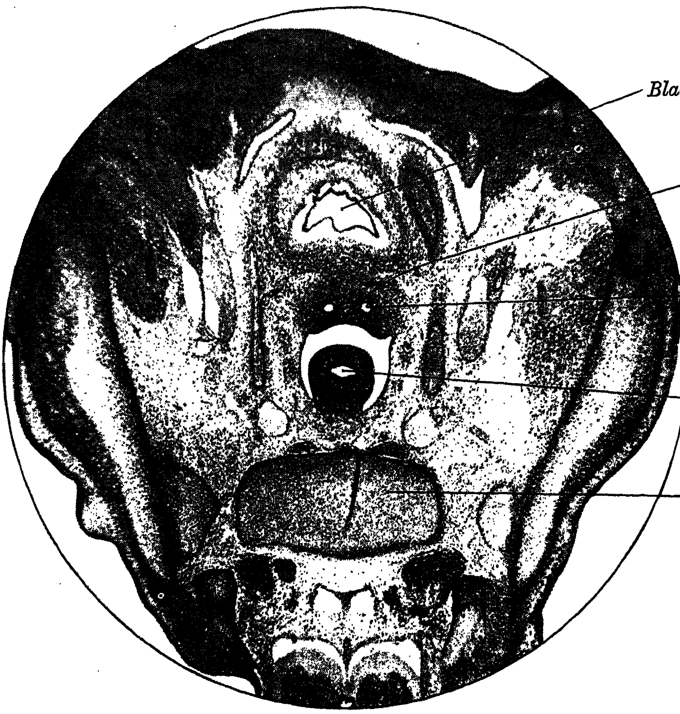
FIG. 242.—Transverse section through the pelvic part of a human embryo, to show the formation of the genital cord and the inguinal folds. (From Quain's Elements of Anatomy, II edition, vol. i., Embryology.)



mesonephric duct but, owing to differences in rate of growth, it comes to be connected to the lateral aspect of that structure. Thereafter the caudal end of the mesonephric duct becomes incorporated in the developing bladder and the orifice of the ureter opens into the bladder on the lateral side of the opening

of the duct. Later the two orifices become separated still further and, although the ureter retains its point of entry into the bladder, the mesonephric duct opens

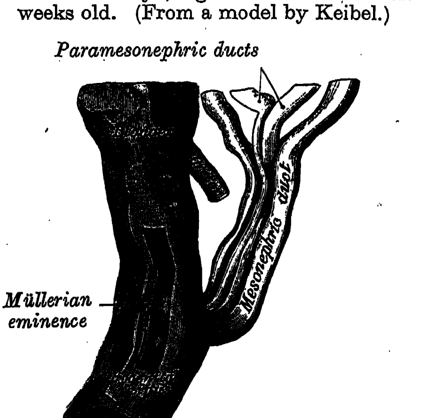
FIG. 243.—Transverse section through the pelvis of a nine weeks old human embryo, male, showing the approximation of the genital cord to the dorsal wall of the urogenital sinus.



into that part of the urogenital sinus which subsequently becomes the prostatic urethra.

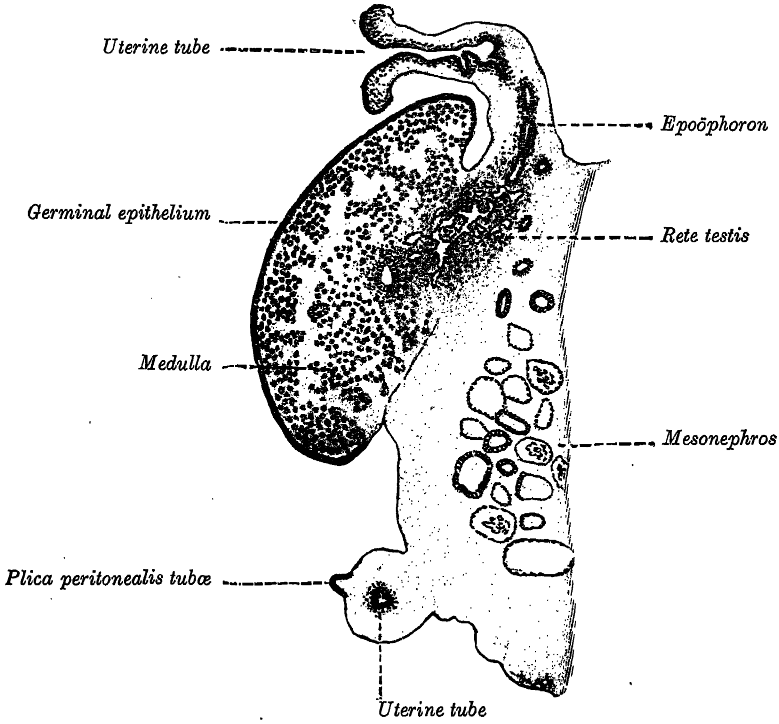
The **paramesonephric** (Müllerian) **ducts**, which are destined to play a very important part in the development of the reproductive system in the female, do not develop until the embryo reaches a length of 10-12 mm. (sixth week). Each commences as a groove-like invagination of the cœlomic epithelium on the dorsilateral aspect of the mesonephric ridge near its cephalic end, and its blind end grows tailwards as a solid rod of cells which acquires a lumen as it lengthens. Throughout the extent of the mesonephros it lies on the lateral side of the mesonephric duct. At the caudal end of the mesonephros, which it reaches in the eighth week, it bends medially (fig. 248, I.) and crosses ventral to the mesonephric duct to enter the genital cord (fig. 242), where it bends caudally in close apposition with its fellow of the opposite side. The two ducts reach the dorsal wall of the urogenital sinus during the third month, and their blind ends produce an elevation on it termed the *Müllerian tubercle* or *eminence* (fig. 244). Each paramesonephric duct consists of an upper vertical, an intermediate horizontal, and a lower vertical portion. The upper vertical part forms the

FIG. 244.—The urogenital sinus of a female human embryo, eight and a half to nine weeks old. (From a model by Keibel.)



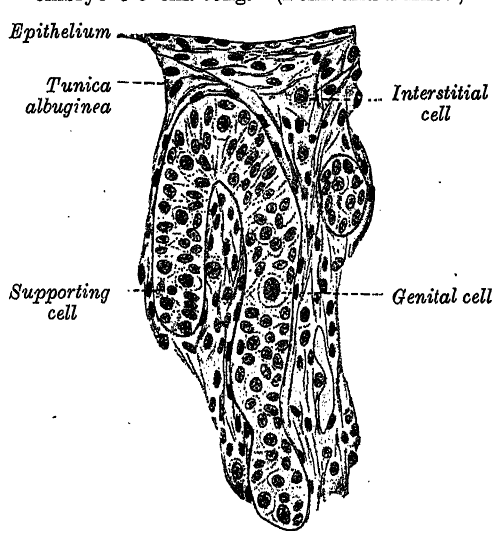
uterine tube, and the original cœlomic invagination remains as the pelvic opening of the tube, the fimbriae becoming defined as the cephalic end of the

FIG. 245.—A longitudinal section of the ovary of a cat embryo, 9·4 cm. long. Schematic. (After Coert, from Hertwig's Handbuch der Entwickelungslehre.)



mesonephros degenerates. The lower vertical parts of the two ducts fuse with each other to form the *uterovaginal canal*, and as the uterine section enlarges it

FIG. 246.—A section through a testis cord of the testis of a human embryo 3·5 cm. long. (Felix and Bühler.)



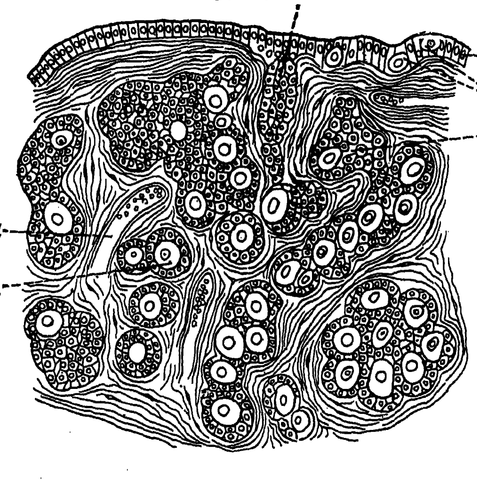
takes in the horizontal parts to form the fundus and most of the body of the adult uterus.

The caudal end of the uterovaginal canal becomes occluded by the proliferation of its lining epithelium, which gives rise to the formation of a central and two lateral vaginal bulbs.* These solid epithelial masses extend tailwards, increasing the size of the area of contact of the vagina with the urogenital sinus and forming a conspicuous projection on the dorsal wall of the latter. The vagina grows much more rapidly than the surrounding parts and, owing to the way in which its caudal end enlarges and encroaches on the dorsal wall of the urogenital sinus, that structure becomes definitely shortened. The vaginal invagination, covered on the one hand by sinus epithelium and on the other by vaginal epithelium, constitutes the *hymen,* and it later breaks down centrally to form the hymeneal orifice.

In the male the paramesonephric (Müllerian) duct atrophies, but a vestige of its cephalic end persists as the *appendix testis.* The fused terminal portions of the two ducts (fig. 243) form the *prostatic utricle,* which opens into the floor of the prostatic part of the urethra.

The genital glands.—The first indication of the formation of the genital gland is the appearance of an area of thickened epithelium on the medial side

Fig. 247.—A section through the ovary of a new-born child. (Waldeyer.)



of the mesonephric ridge in the fifth week. Elsewhere on the surface of the ridge the cœlomic epithelium is one or two cells thick, but over the genital area it is many layered. The thickening rapidly extends in a longitudinal direction until it covers nearly the whole of the medial surface of the ridge. The thickened epithelium continues to proliferate, displacing the Malpighian corpuscles of the mesonephros in a dorsilateral direction, and forming a projection into the cœlomic cavity which is termed the *genital ridge.* Surface depressions form along the limits of the ridge, which is thus connected to the mesonephros by an originally broad *mesogenitale.* In this way the mesonephric ridge becomes subdivided into a lateral part, containing the mesonephros and the mesonephric (Wolffian) and paramesonephric (Müllerian) ducts, which is termed the *mesonephric fold*, and a medial part, termed the *genital fold* (fig. 241).

Up to the seventh week the genital gland possesses no differentiating features. The epithelium proliferates and sends a number of cellular cords into the underlying mesoderm of the mesonephric ridge. In the male all the progenitors of the definitive sex cells are to be found in the cords, but in the female a large number remain behind in the surface epithelium. An ingrowth of mesenchyme occurs at this stage in the male, cutting off the *testis cords* from the surface and rapidly thickening to form the *tunica albuginea.* In the female this

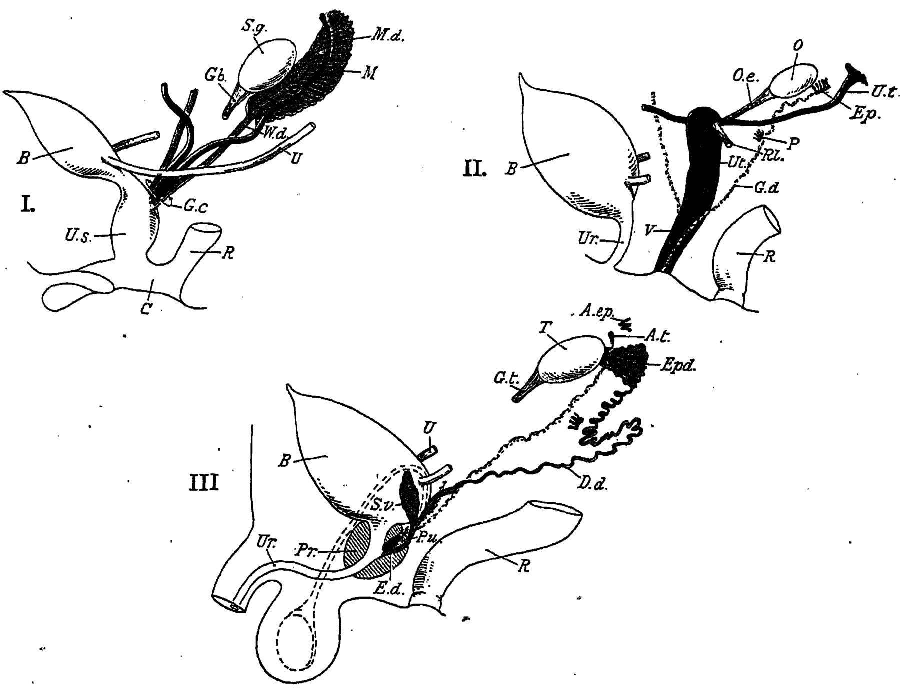
* J. Ernest Frazer and Alice Bloomfield, *Journal of Anatomy*, vol. lxii. *See also* Arthur K. Koff, *Contributions to Embryology*, vol. xxiv. 1933.

mesenchymal ingrowth is much less obvious and offers a feature which serves to distinguish the testis from the ovary.

The **testis**.—The cellular cords enlarge and their inner ends converge towards the site of the hilum, where they unite in a network which ultimately becomes the *rete testis*. The outer parts of the testis cords become the seminiferous tubules, but certain epithelial derivatives occupy the intervals between the cords and subsequently form the interstitial cells. The cords of the rete

FIG. 248.—Diagrams to show the development of the male and female generative organs from a common type (after Allen Thomson). I. The condition in the embryo at the beginning of the third month. II. The female type of sexual organs. III. The male type of sexual organs.

The paramesonephric duct and its derivatives are shown in blue; the mesonephros, its duct and their derivatives are shown in red. The broken blue and red lines indicate that the structures shown normally disappear. The paradidymis is shown in III., but is not labelled.



A.ep. Appendix of epididymis. *A.t.* Appendix testis. *B.* Bladder. *C.* Cloaca. *D.d.* Ductus deferens. *Epd.* Epididymis. *E.d.* Ejaculatory duct. *Ep.* Epoöphoron. *G.c.* Genital cord. *G.d.* Duct of epoöphoron. *G.t.* Gubernaculum testis. *Gb.* Gubernaculum. *M.* Mesonephros. *Md.* Paramesonephric duct. *O.* Ovary. *O.l.* Ovarian ligament. *P.* Paroöphoron. *Pr.* Prostate. *P.u.* Prostatic utricle. *R.* Rectum. *R.l.* Round ligament of uterus. *S.g.* Sexual gland. *S.v.* Seminal vesicle. *U.* Ureter. *Ur.* Urethra. *U.s.* Urogenital sinus. *U.* Uterus. *U.t.* Uterine tube. *V.* Vagina. *W.d.* Mesonephric duct.

testis become connected to the five to twelve persisting cephalic tubules of the mesonephros (p. 185), which constitute the efferent ducts of the testis. The seminiferous tubules do not acquire lumina until the seventh month, but the rete tubules acquire theirs at a somewhat earlier stage.

According to the above description the rete testis is derived from the epithelium of the genital ridge, but the view is widely held that the rete testis is derived from outgrowths from the tubules of the mesonephros or from the capsules of the Malpighian corpuscles, and becomes secondarily connected to the testis cords. However this may be, it is clear that the seminiferous tubules are brought into communication with the cephalic end of the mesonephric duct through the five to twelve most cephalic of the persisting tubules, which become exceedingly convoluted and form the lobules of the head of the epididymis. The mesonephric duct, which was the primitive ureter of the mesonephros, becomes the canal of the epididymis and the vas deferens of the testis.

The **ovary**.—The cellular cords, which appear in the indifferent stage of the genital gland, are termed the *medullary cords* of the ovary, and the sex cells which they contain, proliferate and develop into oöcytes, but although these oöcytes undergo the initial changes leading to maturation, they never form mature ova. It is said that all the sex cells derived from the medullary cords undergo degenerative changes and disappear. A second invasion of the underlying mesenchyme now occurs, and new cords grow in from the surface epithelium. All the sex cells are included in this new ingrowth, and the ova become separated from one another by an irregularly arranged growth of connective tissue. Each ovum assumes a covering of connective tissue cells, and in this way the rudiments of the ovarian follicles are formed.

It is generally believed that the primary sex cells or *gonocytes* are differentiated at an early stage in the development of the embryo, and that, prior to the appearance of the genital ridge, they are situated in the wall of the yolk-sac at the margins of the embryonic area. From this position they migrate to the root of the dorsal mesentery and thence to the genital ridge. Arrived at their destination the primary sex cells lose all their characteristic features, and become indistinguishable from the neighbouring cells of the cœlomic epithelium. Probably the definitive sex cells are derived partly from the primary sex cells, and partly from the epithelial cells.

The descent of the testis.—At first the testis lies on the dorsal abdominal wall, but, as it enlarges, its cephalic end degenerates, and the whole organ therefore assumes a more caudal position. The testis is attached to the mesonephric fold by a peritoneal fold, termed the *mesorchium* (fig. 241) (the mesogenitale of the undifferentiated genital gland), which contains the testicular vessels and nerves together with a quantity of undifferentiated mesenchyme. In addition, it acquires a secondary attachment to the ventral abdominal wall, which has a considerable influence on its subsequent movements. At the point where it bends medially to form the genital cord (p. 185), the mesonephric fold becomes connected to the lower part of the ventral abdominal wall by a fold of peritoneum which is termed the *inguinal fold* (fig. 242). The mesenchymal cells included in the inguinal fold form a cord, which extends from that part of the skin which later forms the scrotum, through the inguinal fold and the mesorchium to the lower pole of the testis. This cord later becomes a fibromuscular bundle and is termed the *gubernaculum testis*. It traverses the site of the future inguinal canal, which is formed around it by the muscles of the abdominal wall as they become differentiated. At the end of the second month the caudal part of the ventral abdominal wall is horizontal but, after the return of the intestines to the peritoneal cavity (p. 170), it grows in length and assumes a vertical position. As a result the umbilical artery pulls up a sickle-shaped peritoneal fold, as it runs ventrally from the dorsal to the ventral wall, and this fold forms the medial boundary of a peritoneal fossa into which the testis projects. This fossa is termed the *saccus vaginalis* and its lower end protrudes down the inguinal canal along the gubernaculum, forming the *processus vaginalis*. The lower pole of the testis is retained in apposition with the deep inguinal ring by the gubernaculum until the seventh month, when it suddenly and rapidly passes through the inguinal canal and gains the scrotum. As it descends it is necessarily accompanied by its peritoneal covering and the adjoining peritoneum from the iliac fossa is drawn down into the processus vaginalis. The distal end of the processus vaginalis, into which the testis projects, forms the tunica vaginalis testis, but the portion associated with the spermatic cord in the scrotum and in the inguinal canal normally becomes obliterated.

The actual cause of the descent of the testis is still uncertain. It has been ascribed, by different investigators, to shortening and active contraction of the gubernaculum, to increased intra-abdominal pressure, to a simple growth process, and to the effect on the convex surface of the gland of the active contraction of the lower fibres of the internal oblique muscle, which squeezes it through the canal.

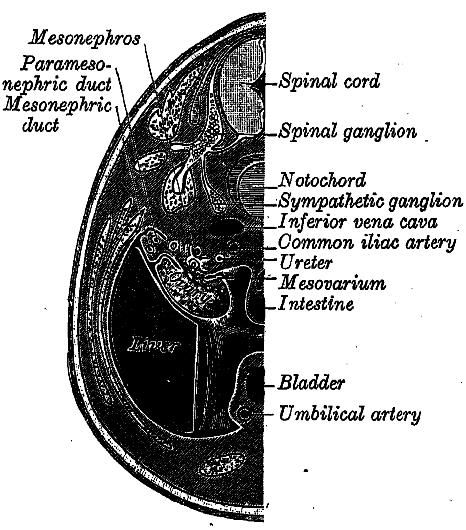
Various abnormalities may occur in connexion with the descent of the testis and the obliteration of the processus vaginalis. The testis may be retained in the abdomen, or it

may fail to reach the scrotum and may then lie in any of the following situations :—(1) in the perineum, (2) at the root of the penis, (3) at the superficial inguinal ring, (4) in the upper part of the thigh. These malpositions are associated with certain additional connexions of the bundles of the gubernaculum testis. The largest bundle normally passes to the scrotum and smaller bundles gain attachment to the perineum, the root of the penis, the pubis, the inguinal ligament, and the neighbourhood of the saphenous opening (fossa ovalis). The testis must follow the processus vaginalis and, should the latter for any reason follow any but the scrotal bundle of the gubernaculum, malposition of the testis will result.

The processus vaginalis may remain completely patent, or its obliteration may be incomplete. When it retains a connexion with the general peritoneal cavity it provides a preformed sac for a potential oblique inguinal hernia. It may be occluded at its upper end and may be shut off from the tunica vaginalis and yet remain patent in the intervening section. The patent portion may become distended with fluid, constituting an encysted hydrocele of the spermatic cord.

The descent of the ovary.—Like the testis, the ovary lies at a lower level in the adult than it does in the early months of fœtal life, but it does not leave the pelvis to enter the inguinal canal save under abnormal conditions. Connected to the medial portion of the mesonephric fold by the mesovarium, which is homologous with the mesorchium, the ovary is also attached to the ventral abdominal wall through the medium of the inguinal fold. In this fold the fibro-muscular gubernaculum develops and, as it traverses the mesonephric fold, it acquires an additional attachment to the cornu of the uterus ; its lower portion forms the round ligament of the uterus and its upper part the ligament of the ovary, these two structures together being homologous with the gubernaculum testis in the male. This new attachment serves to anchor the ovary and to restrict its movements. At first the ovary is attached to the medial side of the mesonephric fold, but owing to the way in which the two mesonephric folds unite to form the genital cord (p. 185) it is found connected to the posterior layer of the broad ligament of the uterus in the adult.

Fig. 249.—A transverse section through a human embryo, eight and a half to nine weeks old. (From a model by Keibel.)



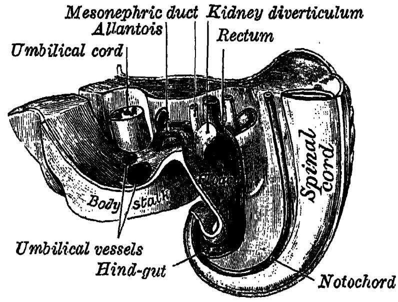
The saccus vaginalis forms in the female as in the male ; its prolongation into the inguinal canal, which is termed the *canal of Nuck*, normally undergoes complete obliteration, but it may remain patent and form the sac of an oblique inguinal hernia. At birth the ovary and the corresponding end of the uterine tube lie in the false pelvis, and they do not sink down into the true pelvis until it enlarges sufficiently to contain both them and the bladder together with the other pelvic viscera.

The **urinary bladder** is formed partly from the entodermal cloaca and partly from the ends of the mesonephric (Wolffian) ducts. After the separation of the rectum from the cloaca (p. 171), the ventral part of the latter becomes subdivided into three portions : (1) a cephalic *vesico-urethral portion*, continuous with the allantoic canal—into this portion the mesonephric ducts open ; (2) a middle, narrow channel, the *pelvic portion* ; and (3) a caudal, broad, *phallic portion*, closed externally by the urogenital membrane (fig. 252). The second and third parts together constitute the *urogenital sinus*. The vesico-urethral portion incorporates the caudal ends of the mesonephric ducts and the associated ends of the ureteric diverticula, and these give rise to the trigone of the bladder and part of the prostatic urethra. The remainder of the vesico-urethral portion

forms the body of the bladder and part of the prostatic urethra ; its apex is prolonged to the umbilicus as a narrow canal. In postnatal life the urachus is drawn downwards as the bladder descends, but its blind upper end remains connected to one or both of the obliterated umbilical arteries. Its lumen is retained throughout life, and its lower end frequently communicates with the bladder near its vertex.*

The **prostate** arises during the third month as a number of outgrowths from the proximal part of the urethra. These outgrowths, some fourteen to twenty

FIG. 250.—The tail-end of a human embryo, about thirty-five days old. (From a model by Keibel.)

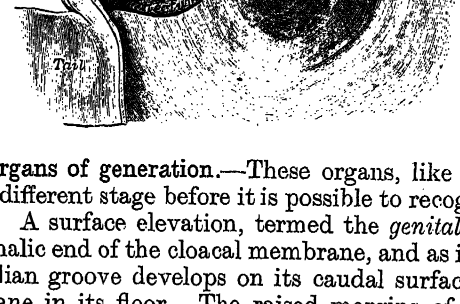


in number, arise mainly from the lateral aspects of the tube, but some develop from its dorsal aspect and a few from its ventral aspect. Most of these outgrowths occur caudal to the orifices of the mesonephric (Wolffian) ducts, but about one-third occur on the cephalic side. The outgrowths, which are at first solid, become tubular and invade the surrounding mesenchyme, which is being differentiated into muscular tissue.

Similar outgrowths occur in the female, but they remain in a rudimentary condition and form the para-urethral ducts.

The *bulbo-urethral glands* in the male, and *greater vestibular glands* in the female, arise as diverticula from the epithelial lining of the urogenital sinus.

FIG. 251.—The tail-end of a human embryo, about six weeks old. (From a model by Keibel.)



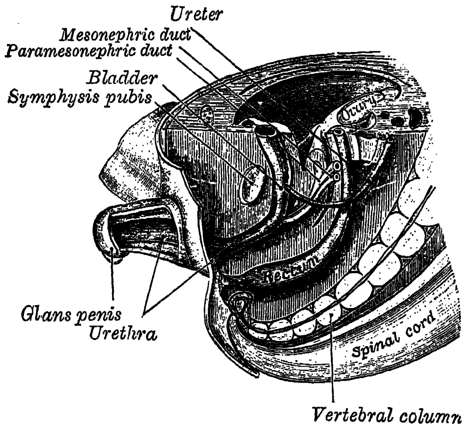
The **external organs of generation**.—These organs, like the genital glands, pass through an indifferent stage before it is possible to recognise distinguishing sexual characters. A surface elevation, termed the *genital* or *cloacal tubercle*, appears at the cephalic end of the cloacal membrane, and as it lengthens to form the *phallus*, a median groove develops on its caudal surface and includes the urogenital membrane in its floor. The raised margins of the groove, which are named the *genital folds* (fig. 254), terminate behind in a transverse ridge, situated immediately in front of the anus.† In the majority of cases in male

* R. C. Begg, *Journal of Anatomy*, vol. lxiv. 1930.

† According to Ellsworth M. Tench (*loc. cit.*) the genital folds are continuous behind with the anal tubercles, which do not fuse with each other in front of the anus until a later stage.

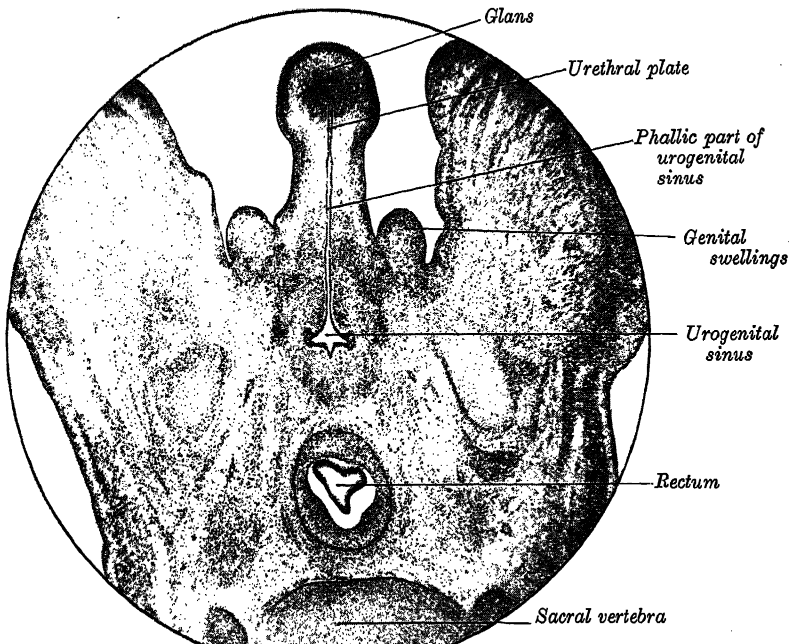
embryos the groove reaches the apex of the phallus, whereas in female embryos it does not extend so far.* By this feature the sex of an embryo may frequently, but not invariably, be determined as early as the seventh week.

FIG. 252.—The tail-end of a human embryo, eight and a half to nine weeks old. (From a model by Keibel.)



Prior to the rupture of the urogenital membrane the urogenital sinus extends ventrally into the phallus and is continued to its apex as a sagitally placed epithelial plate, termed the *urethral plate* (fig. 253). The rupture of the urogenital membrane provides a common perineal orifice for both the generative and the urinary tracts, and this orifice is bounded at the sides by the genital folds.

FIG. 253.—Transverse section through the lower part of the pelvis of a nine weeks old human embryo.

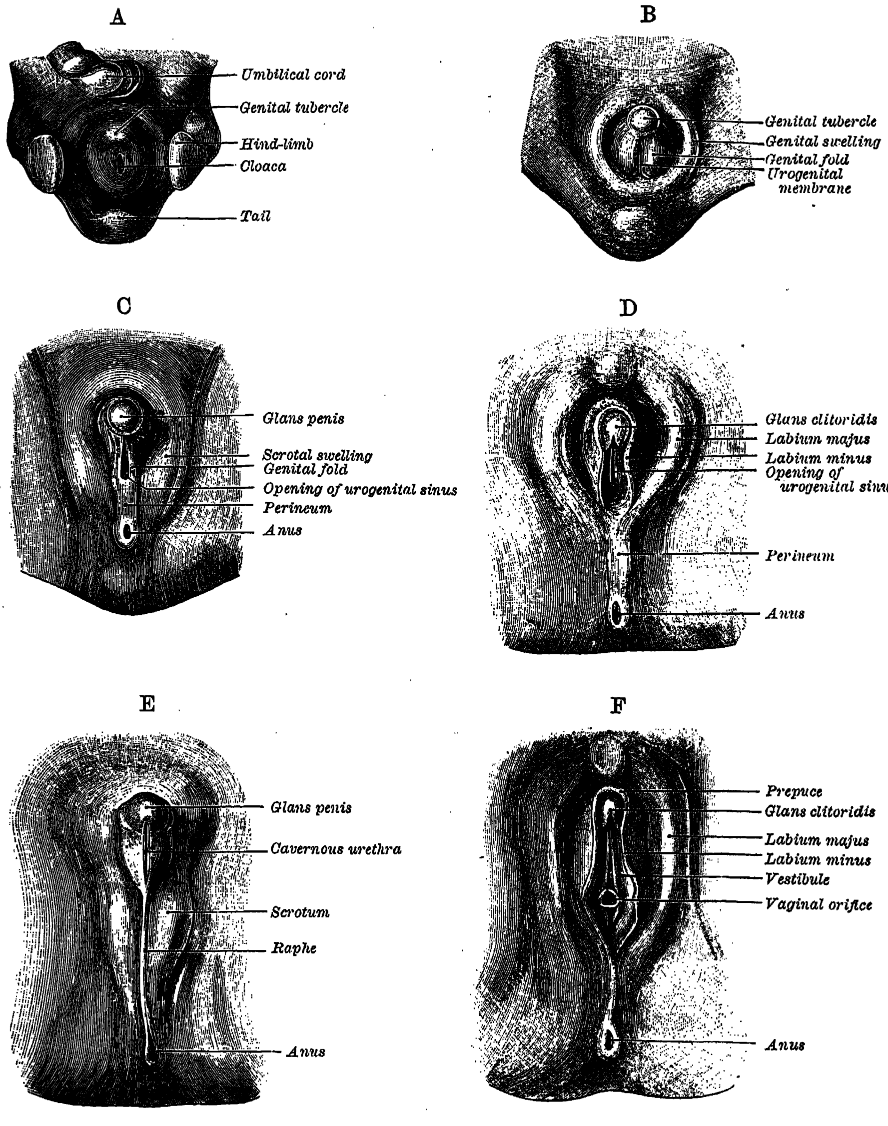


* M. H. Spaulding, *Contributions to Embryology*, No. 61, 1921; K. M. Wilson, *Contributions to Embryology*, No. 91, 1926; A. Szenes, *Morphol. Jahrbuch*, Bd. 54.

While these changes are in progress two *genital swellings* (labioscrotal folds) appear, one on each side of the base of the phallus, and extend caudally, separated from the genital folds by distinct grooves (fig. 254).

In the male, the phallus enlarges to form the penis, and its apex constitutes the glans. The genital swellings meet each other ventral to the anus and unite to form the scrotum. The genital folds fuse with each other from behind

Fig. 254.—Stages in the development of the external sexual organs in the male and female. (From the Ecker-Ziegler models.)



forwards, enclosing the penile part of the urethra and completing the ventral aspect of the penis. In this way, as the phallus lengths, the urogenital orifice is carried onwards until it reaches the base of the glans, where it forms a primary meatus. The urethral plate splits and a trough is formed, which extends from the primary meatus forwards to the apex of the glans. The primary meatus becomes closed and the margins of the trough unite from behind forwards, until only the definitive (secondary) meatus remains. The *prepuce* is formed by the ingrowth of a ring-like plate of ectoderm which burrows into the superficial part of the glans. The ring is deficient ventrally

and the gap indicates the site of the frenulum. By the breaking down of its central cells the plate is split into two lamellæ, and a cutaneous fold, the prepuce, is liberated to form a hood-like covering for the glans. 'Adherent prepuce is not an adhesion really, but a hindered central desquamation' (Berry Hart).

In the female the phallus, which exceeds the male phallus in length in the early stages, becomes the clitoris. The genital swellings remain separate as the labia majora and the genital folds also remain ununited, forming the labia minora. The perineal orifice of the urogenital sinus is retained as the cleft between the labia minora, above which the urethra and vagina open. The prepuce of the clitoris develops in the same way as the homologous structure in the male.

The **urethra.**—In the female, the whole of the urethra is derived from the vesico-urethral portion of the cloaca (p. 193). It is homologous with that part of the prostatic urethra in the male which lies headwards of the orifices of the prostatic utricle and the ejaculatory ducts.

In the male, the prostatic part of the urethra headwards of the orifice of the prostatic utricle is derived from the vesico-urethral portion of the cloaca and the incorporated caudal ends of the mesonephric ducts. The remainder of the prostatic part, the membranous part and probably the part within the bulb, are all derived from the urogenital sinus. The succeeding portion, as far as the glans, is formed by the fusion of the genital folds, while the section within the glans is formed from the urethral plate.

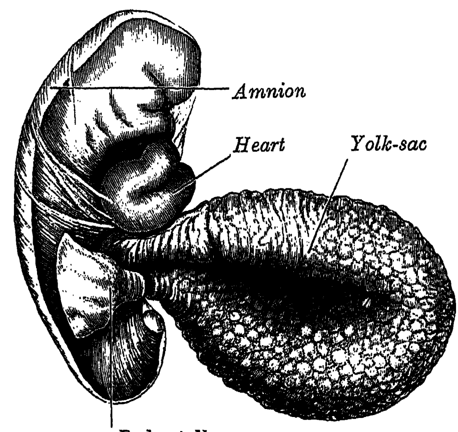
The subjoined table shows the homologies of the various parts of the urogenital system in the male and in the female (fig. 248).

Indifferent	Male	Female
Genital gland	Testis	Ovary
Gubernacular cord	Gubernaculum testis	Ligament of ovary Round ligament of uterus
Mesonephros (Wolffian body)	(?) Appendix of epididymis	(?) Appendices vesiculosæ
	Efferent ducts of testis	Epoöphoron
	Coni vasculosi of head of epididymis	
	Paradidymis	Paroöphoron
	Ductuli aberrantes	
Mesonephric duct (Wolffian duct)	Duct of epididymis	Duct of epoöphoron
	Ductus deferens	
	Ejaculatory duct	
	Part of bladder and prostatic urethra	Part of bladder and urethra
Paramesonephric ducts (Müllerian ducts)	Appendix of testis	Uterine tubes
		Uterus
	Prostatic utricle	Vagina
Allantoic canal	(?) Urachus	(?) Urachus
Cloaca, dorsal portion of	Rectum and upper part of anal canal	As in male
ventral portion of	Most of the urinary bladder and part of prostatic urethra	Most of the urinary bladder, and the urethra
urogenital sinus	Prostatic urethra (below prostatic utricle)	Bulbo-vestibular glands
	Bulbo-urethral glands	
	Remainder of urethra	Vestibule
Genital swellings	Scrotum	Labia majora
Genital folds	Ventral aspect of penis	Labia minora
Genital tubercle	Penis	Clitoris

Congenital defects of the urethra, due to arrests of development, are not uncommon in the male. The urethra may open on the ventral aspect of the penis at the base of the glans, and the portion of the urethra which is normally derived from the urethral plate is absent. This constitutes the simplest form of *hypospadias*. In more severe cases the genital folds fail to fuse, and the urethra opens on the ventral aspect of a malformed penis just in front of the scrotum. A still greater degree of this malformation is accompanied by failure of the genital swellings to unite with each other. In these cases the scrotum is divided and, as the testes are frequently undescended, the resemblance to the labia majora is very striking. Male children suffering from this deformity are often mistaken for girls.

Maldevelopment of the cloacal or urogenital membranes is a less common condition, but three varieties of it can be distinguished. (1) In *epispadias* the urethra opens on the dorsal aspect of the penis at its junction with the anterior abdominal wall. (2) In *extroversion of the bladder* * the lower part of the anterior abdominal wall is occupied by an irregularly oval area, covered with mucous membrane, on which the two ureters open. Around its periphery this extroverted area, which is lined by transitional epithelium, becomes continuous with the skin. (3) In *extroversion of the cloaca* the condition is very similar,

FIG. 255.—A human embryo, 2·6 mm. long. (His.)



but is complicated by the presence of intestinal openings in the median plane. In (3) the cloacal membrane is probably abnormally elongated and ruptures prematurely and throughout its whole extent, prior to the formation of the urorectal septum. In (2) the maldevelopment occurs after the separation of the ventral from the dorsal part of the cloaca. The urogenital membrane extends further headwards than it does in normal cases and the genital tubercle forms at its caudal limit. Rupture of the membrane throws the bladder open to the exterior. In (1) a similar condition exists, but rupture of the urogenital membrane is localised so that the anterior wall of the bladder is not affected.

THE FORM OF THE EMBRYO AT DIFFERENT STAGES OF ITS GROWTH

To determine the precise age of any given human embryo is a matter of great difficulty, especially in the earlier stages, even when the date of the fertilising coitus is known. In 1899 Peters † described a specimen, the age of which he computed at from three to four days, but Bryce and Teacher,‡ in the light of the specimen described by them, have estimated its age as from thirteen and a half to fourteen and a half days. A very young human embryo was found by Miller in 1913 in tissue removed by curettage. The sections have been examined by Streeter,§ who estimates the age at from ten to eleven days. There were no chorionic villi but the amniotic vesicle was present and a rudiment of the entodermal vesicle was recognisable. Stieve ** has recently described an ovum (Embryo Werner) which he

* G. M. Wyburn, *Journal of Anatomy*, vol. lxxi. 1937.

† Hubert Peters, *Die Einbettung des menschlichen Eies*, 1899.

‡ Bryce and Teacher. (*Early Development and Imbedding of the Human Ovum*, 1908.)

§ Streeter, G. E. *Contributions to Embryology*, No. 92, 1927.

** H. Stieve. *Zeitschrift für Mikroskopisch-Anatomische Forschung*, Bd. 40, 1936.

regards as representing an intermediate stage between the Miller ovum and the Peters ovum. Primary chorionic villi are present and a trophoblastic shell limits a blood-filled intervillous space. The ectodermal vesicle is present and its ventral surface is in relation with a single layer of cells which is regarded as representing the roof of the entodermal

Fig. 256.—A human embryo, 4·2 mm. long. (His.)

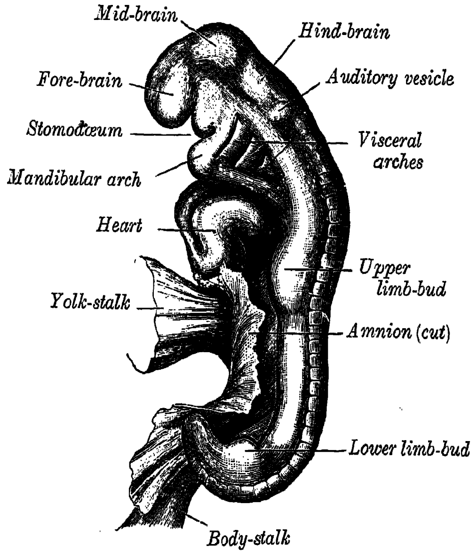
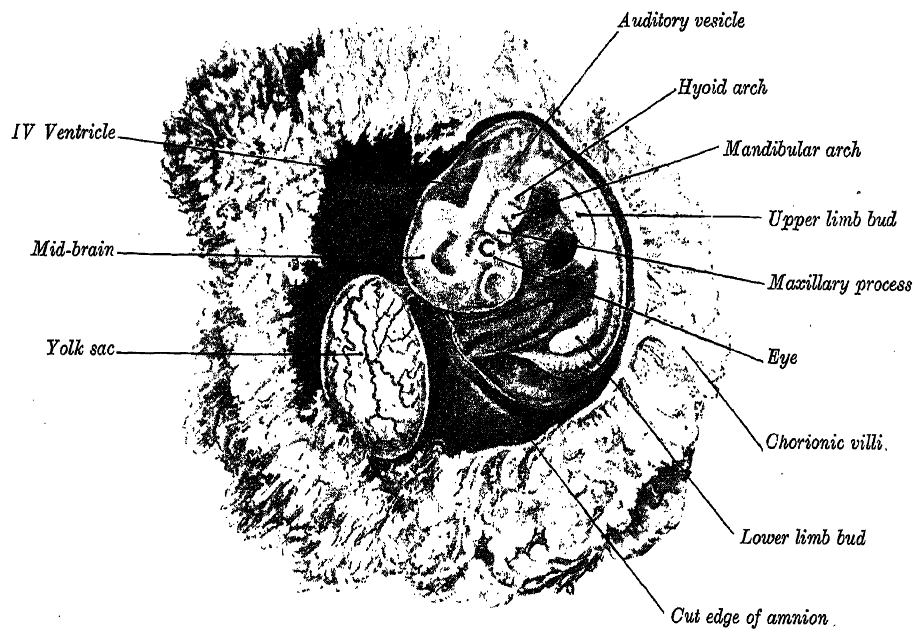


Fig. 257.—A human embryo, about 8 mm. long. (Drawn from a stereoscopic photograph taken before fixation.)



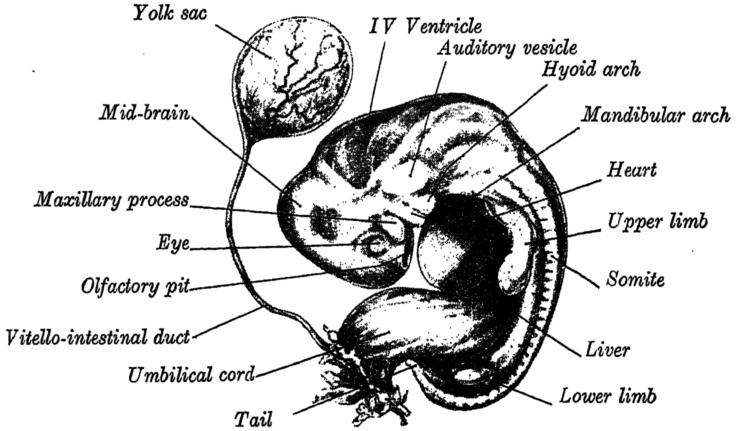
vesicle. The rest of the vesicle is outlined in the magma cavity but its wall is not cellular (see p. 55, footnote *). Bryce and Teacher, Grosser,* and von Mollendorff † have all described early human embryos of approximately the same stage. The Teacher-Bryce

* Grosser, O. *Zeitschrift für Anatomie und Entwickelungsgeschichte,* 1922.

† von Mollendorff, W. *Zeitschrift für Anatomie und Entwickelungsgeschichte,* 1921.

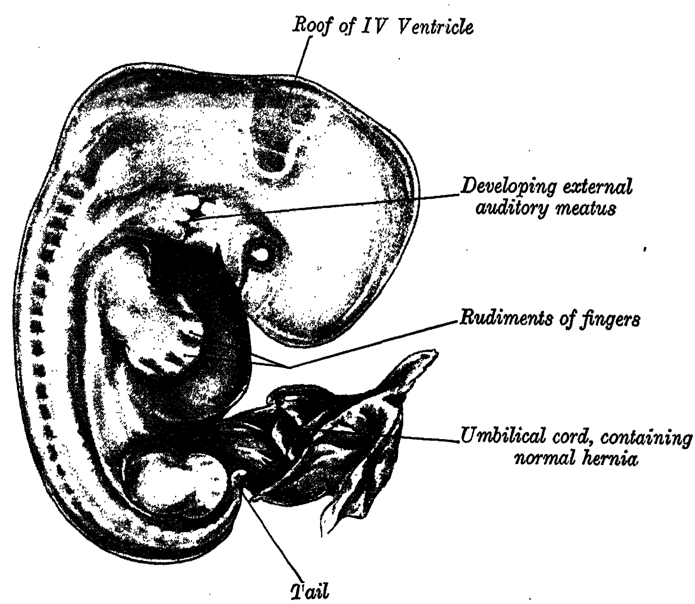
ovum (T.B.I.) was the product of an early abortion, and the ovum was discharged completely enveloped by decidua. The authors estimate its age as from thirteen to fourteen days. It took the form of a blastocyst (fig. 74) with a diameter of approximately 6 mm., which was surrounded by a well-developed, reticular plasmodial trophoblast lined by

FIG. 258.—Human embryo, about 9 mm. long. (Drawn from a stereoscopic photograph.)



cytotrophoblast. Within the blastocyst was contained the embryonic rudiment, which consisted of two small vesicles; the larger of the two was identified as the ectodermal or amnio-embryonic vesicle, and the smaller as the entodermal vesicle or yolk-sac. The primary mesoderm, which filled the blastocyst and surrounded the vesicles, consisted of a fluid matrix containing numerous cellular elements. The cells of the ectodermal vesicle

FIG. 259.—Human embryo, about 15 mm. long. (Drawn from a stereoscopic photograph.)



showed no differentiation into the amnion and the embryonic area, so that the specimen was definitely younger than the Peters ovum, in which the embryonic ectoderm was already defined.

During the third week differentiation commences in the embryonic area. The primitive streak and node, the head process and the neural groove appear. The allanto-enteric diverticulum is present and, by the end of the period, head and tail folds are in process of formation (fig. 95).

During the fourth week the head and tail folds are completed. The primary cerebral vesicles can be recognised and the neural groove commences to close (fig. 255). The auditory vesicle appears, but as yet the face is unrecognisable and the neck is not apparent. The heart forms a prominent elevation, immediately caudal to the stomodæum, and segmentation of the mesoderm is begun. The vitello-umbilical veins communicate with the common sinu-atrial chamber and the embryonic circulation is established; at the end of the period the embryo is about 2·5 mm. long.

In the fifth week the embryo becomes markedly curved on itself and becomes more definitely pinched off from the yolk-sac. The lens vesicle has closed and is separated from the covering ectoderm. The olfactory placodes are present, and the maxillary and fronto-

Fig. 260.—A human embryo, about 23 mm. long. (His.)

nasal processes can be recognised. The branchial arches and grooves appear, indicating the position of the neck, and the rudiments of the limb-buds can be identified (fig. 256). By the end of the period some thirty to thirty-six somites are present and the crown-rump length of the embryo has reached 5·5 mm.

In the sixth week the curvature of the embryo is further increased. The head is in contact with the umbilical cord and may almost meet the long, curved tail. The olfactory pits deepen, and the maxillary, lateral nasal and globular processes begin to fuse. The mandibular and hyoid arches meet their fellows in the median plane, and the neck commences to appear. The liver forms a surface prominence between the heart and the umbilical cord. The limb-buds increase in length and three segments can be recognised in each. By the end of the sixth week the embryo has increased to 11 mm. crown-rump length.

In the seventh and eighth weeks the flexure of the head is gradually reduced and the neck is somewhat lengthened. The upper lip is completed and the nostrils are directed forwards; the palate is not completely developed. The eyelids are present in the shape of folds above and below the eye, and the different parts of the auricle are distinguishable. The external genitalia are present and may show sexual differences by the end of the seventh week (p. 195). The tail begins to disappear. The fingers and toes can be recognised. By the end of the eighth week the embryo has attained a crown-rump length of about 25 mm. and now passes into the fœtal period.

In the third month the head is extended and the neck is lengthened. The eyelids meet and fuse, remaining closed until the end of the sixth month. The limbs are well developed and nails appear on the digits. The normal umbilical hernia is reduced and by the end of this month the crown-rump length of the fœtus is about 10 cm.

In the fourth month lanugo appears on the body, and by the end of the month the fœtus has reached a crown-rump length of about 14 cm., and a total length—i.e. including the legs—of about 22 cm.

During the fifth month the first movements of the fœtus are usually observed. The eruption of hair on the head commences, and the vernix caseosa begins to be deposited. By the end of this month the total length of the fœtus is nearly 30 cm.

In the sixth month the deposit of vernix caseosa is considerable. The papillæ of the skin are developed and the free borders of the nails project from the corium of the dermis. From vertex to heels the total length of the fœtus at the end of this month is about 33 cm. The weight is about 1 kilogram.

In the seventh month the pupillary membrane atrophies, and the eyelids are open. The testis descends with the vaginal sac of the peritoneum. The skin is red and wrinkled, giving the fœtus a prematurely aged appearance. From vertex to heels the total length at the end of the seventh month is about 40 cm. The weight is about 1·5 kilograms.

During the eighth month the skin is entirely coated with vernix caseosa, and the lanugo begins to disappear. Subcutaneous fat has been developed to a considerable extent, and the fœtus presents a plump appearance. The total length, i.e. from head to heels, at the end of the eighth month is about 45 cm., and the weight varies between 2 and 2·5 kilograms.

At the end of the ninth month the lanugo has largely disappeared from the trunk. The umbilicus is almost in the middle of the body and the testes are in the scrotum. The fœtus weighs from 3 to 3·5 kilograms, and measures from head to heels about 50 cm.

OSTEOLOGY

THE general framework of the body is built up mainly of a series of bones, supplemented in certain regions by pieces of cartilage; this bony and cartilaginous framework constitutes the *skeleton* (fig. 261).

In comparative anatomy the term skeleton has a wider application, for in some of the lower animals hard, protecting and supporting structures are developed in association with the skin. In such animals the skeleton comprises an internal or deep skeleton, termed the *endoskeleton*, and an external or superficial, termed the *exoskeleton*. In the human subject the exoskeleton is very rudimentary, its only important representatives being the nails and the enamel of the teeth, and therefore, in human anatomy, the term skeleton is confined to the endoskeleton; this is divisible into an *axial* part, which comprises the bones of the head and trunk, and an *appendicular* part, which comprises the bones of the limbs. The minute structure and the physical properties of bone, together with the process of bone formation and growth, are described on pages 18 to 27. The bones available for study in articulated skeletons and as separate entities have been subjected to a process of maceration, by which they are denuded of all the structures attached to them, viz., muscles, ligaments, periosteum and articular cartilage Subsequently they are allowed to dry for a prolonged period, with the result that the fat in the marrow drains away and what is left of the marrow itself shrivels up, leaving the bone clean, dry and easy to handle.

Function of bones.—Bones provide the central axis and give form to the body. Many of them are adapted to give support to the weight of the body, but they may fulfil some additional function, e.g. the thigh bones support the weight of the body in standing, walking and running, but they also provide the levers which are essential for locomotion. Other bones give protection to underlying or contained structures, e.g., the cranium protects the contained brain, and the sternum and ribs overlie the heart and lungs and give them some measure of protection. Others, again, afford areas for the attachment of muscles and provide the levers which facilitate speedy and efficient movements. Bones, therefore, constitute an important part of the locomotor apparatus of the body, but to enable them to function as levers for the production of movements they must be connected by muscles, and movable joints or articulations must be present where individual bones come into contact with one another.

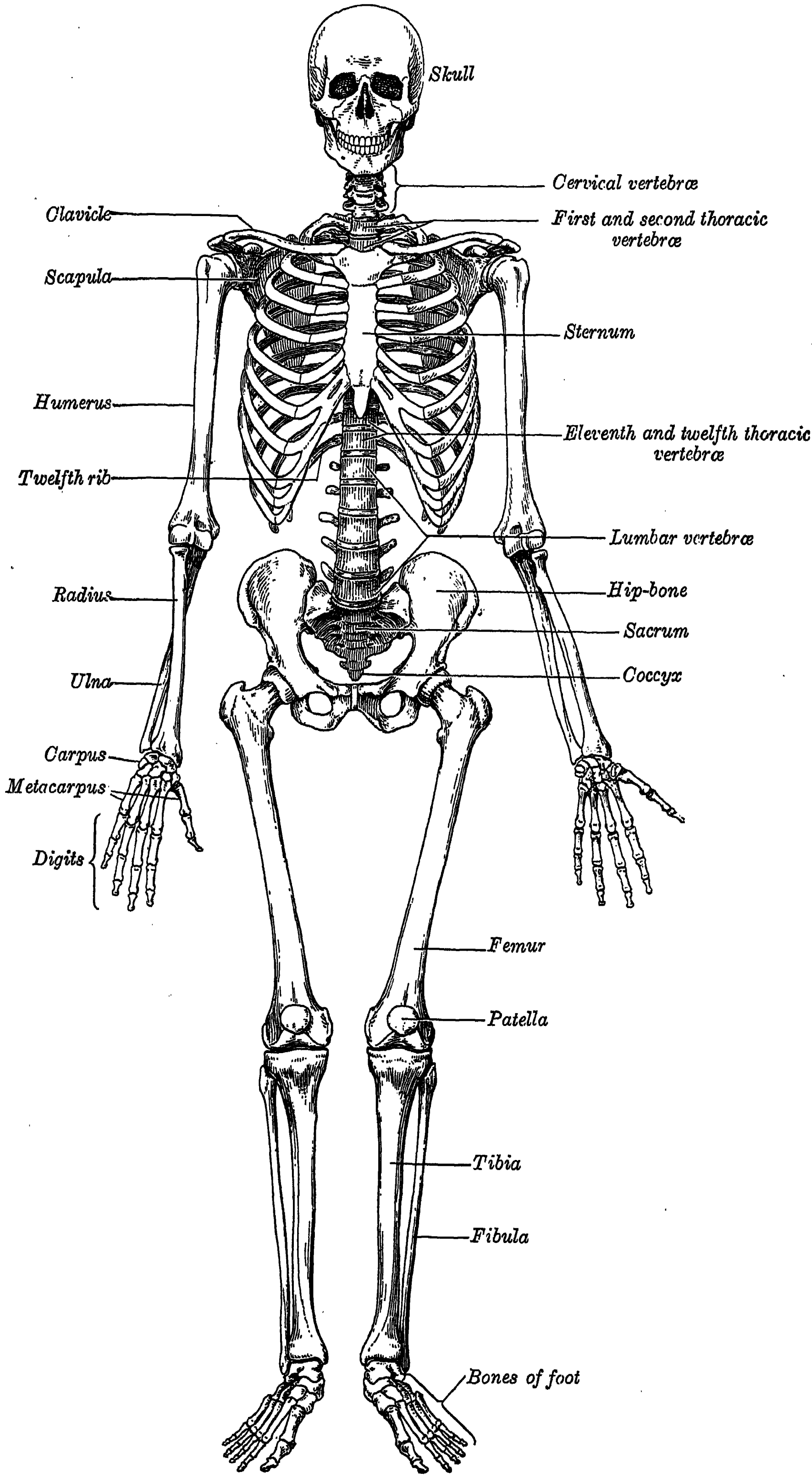
Bones are divisible into four classes: *long*, *short*, *flat*, and *irregular*.

The **long bones** are found in the limbs, where they form levers; each has a shaft and two ends. The *shaft* is tubular, and its central cavity is termed the *medullary cavity*; the wall consists of dense, compact substance of considerable thickness in the middle part of the shaft of the bone, but becoming thinner towards the ends; projecting into the medullary cavity there is some spongy substance, scanty in the middle of the body of the bone but plentiful towards the ends. The *ends* are usually expanded for purposes of articulation and muscular attachment; they consist of spongy substance covered by thin compact bone, and are usually developed from one or more secondary or *epiphyseal* centres of ossification (p. 25). The medullary cavity and the spaces in the spongy substance are filled with marrow (*medulla ossium*) (p. 27).

The **short bones.**—Where a part of the skeleton is intended for strength and compactness combined with limited movement it is constructed of a number of short bones, as in the *carpus* and *tarsus*. These bones consist of spongy substance surrounded by a thin crust of compact bone.

The **flat bones.**—Where the principal requirement of the skeleton is to protect delicate structures or provide broad surfaces for muscular attachment the bones are expanded into plates, as in the skull and the shoulder-blades, and are composed of two thin layers of compact bone separated by a variable quantity of spongy substance. In the cranial bones the layers of compact bone are known as the *tables* of the skull; the outer table is thick and tough, the inner thin, dense and brittle. The intervening spongy substance is called the *diploë*, and this, in certain regions of the skull, undergoes absorption, and air-filled spaces, termed *sinuses*, are left between the tables of the skull.

FIG. 261.—Front view of the skeleton. The right hand is in the prone position, the left in the supine position.



The **irregular bones**, from their peculiar form, cannot be grouped under the preceding heads. They consist of spongy substance enclosed within a thin layer of compact bone.

Surfaces of bones.—The surfaces of bones present many and variable features, which call for the use of a number of special descriptive terms. Smooth areas for articulation with other bones are known as *articular surfaces* and, when small, are frequently termed *facets*. A *condyle* is a smooth rounded projection, and a *trochlea* is a pulley-shaped surface; both are covered with articular cartilage in the recent state.

Depressions on bony surfaces are usually termed *fossæ*. They may be large or small, rough or smooth, non-articular or articular.

Any localised elevation or projection on a bony surface constitutes a *process*. A pointed process is called a *spine*, but the term is frequently applied to elongated processes with blunt extremities, e.g. the spines of the vertebræ. The terms *tubercle* and *tuberosity* are used, without much distinction, for localised, rounded elevations, which may possess smooth or roughened surfaces. An *epicondyle* is an elevation placed above an articular surface. A *hamulus* is a hook-like process, and a *cornu* a horn-like process. A sharp, distinct ridge, whether rough or smooth, is termed a *crest*, and if it is wide enough to possess borders they are known as *lips*. A low, narrow ridge is termed a *line*.

A hole in a bone is known as a *foramen*, and the term is often applied to the opening of a bony tunnel, which is termed a *canal*. A groove or furrow is frequently called a *sulcus*, a notch an *incisura*, a gap a *hiatus*, and a thin sheet or plate a *lamina*.

Many other terms are employed occasionally, but those already defined have the widest use.

THE VERTEBRAL COLUMN [COLUMNA VERTEBRALIS]

In all vertebrate animals the central axis of the body consists of a **vertebral column**. As it is essential that provision should be made for a considerable range of movement of the trunk, the column consists, not of a single elongated bone, but of a number of independent, irregular bones, termed the *vertebræ*, which are firmly connected to one another but are capable of a limited amount of movement on one another. The provision of a central axis is not the only function which the column has to subserve. It is built up so as to surround the spinal cord, to which it affords necessary protection. The human vertebral column must also support the weight of the trunk and transmit it to the lower limbs.

The vertebræ are grouped under the names *cervical*, *thoracic*, *lumbar*, *sacral* and *coccygeal* or *caudal*, according to the region in which they lie, but all the vertebræ, not only of man but also of all vertebrate animals, conform to a general plan, and although, at first sight, there may be little resemblance between a cervical vertebra of a giraffe and a human lumbar vertebra, the essential features of both will be found to be identical.

THE GENERAL CHARACTERISTICS OF A VERTEBRA

A **typical vertebra** (fig. 262) is made up of two principal parts, an anterior or ventral, termed the *body*, and a posterior or dorsal, termed the *vertebral arch*; these enclose a foramen, which is named the *vertebral foramen*.

In the articulated column the bodies and the intervertebral discs interposed between them form a continuous pillar, which constitutes the central axis of the body and, in man, supports and transmits the weight of the head and trunk. The vertebral foramina, placed one above another, constitute a canal in which the spinal cord is lodged and protected. Between contiguous vertebræ two *intervertebral foramina*, one on each side, open into the canal and serve for the transmission of the spinal nerves and vessels.

The **body** of a vertebra is more or less cylindrical, but is subject to a wide range of variation in size and shape in different animals and in different regions of the same animal. Its upper and lower surfaces are flattened and roughened to give attachment to the intervertebral discs. In front, it is convex from side to side and

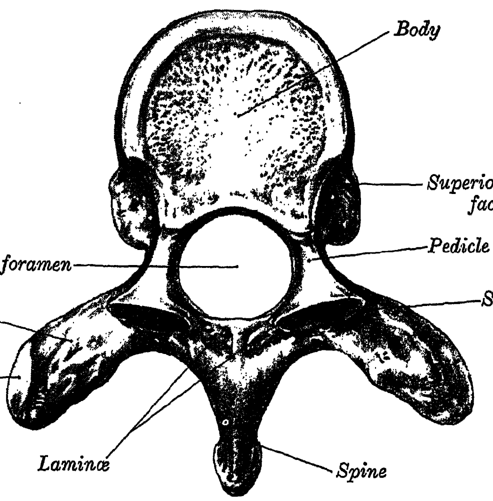
gently concave from above downwards; behind, it is flattened or slightly concave from side to side, and flat from above downwards. On its anterior surface there are a few small apertures for the passage of nutrient vessels; on its posterior surface there is a large irregular aperture (occasionally more than one) for the exit of the basivertebral veins (fig. 263).

The **vertebral arch** has a pair of *pedicles* and a pair of *laminæ*; it supports seven processes, viz., four *articular*, two *transverse* and one *spinous*.

The *pedicles* (*roots of the vertebral arches*) are a pair of short, thick processes, which project backwards from the body at the junctions of its lateral and posterior surfaces. The concavities above and below the pedicles are named the *vertebral notches*; and when the vertebræ are articulated with one another, the notches of contiguous vertebræ form the *intervertebral foramina*, to which reference has already been made.

The *laminæ* are broad plates directed backwards and medially from the pedicles. They fuse in the spine posteriorly, and so complete the posterior boundary of the vertebral foramen.

Fig. 262.—A typical thoracic vertebra. Superior aspect.



The *spine* (*spinous process*) is directed backwards and downwards from the junction of the laminæ, and serves for the attachment of muscles and ligaments. The spines are subject to great variations in size, shape and direction; they provide a series of levers for the movement of extension, or straightening, of the vertebral column and, to a lesser degree, for the movement of rotation.

The *articular processes*, two superior and two inferior, spring from the junctions of the pedicles and laminæ. The superior processes project upwards, and their articular surfaces face more or less backwards; the inferior project downwards, and their articular surfaces face more or less forwards. These processes meet the corresponding processes of the adjoining vertebræ and, while permitting a certain degree of movement, definitely control and restrict its range.

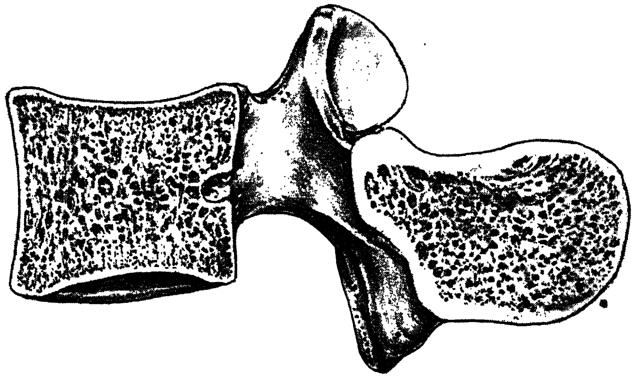
The *transverse processes* project laterally from the junctions of the pedicles and laminæ; they serve for the attachment of muscles and ligaments and are the levers by means of which the rotatory and lateral movements of the vertebræ can be effected. In addition, in the thoracic region they articulate with and limit the movements of the ribs.

The *costal elements* develop as essential constituent parts of each vertebral arch. In certain regions (in man, the thoracic region only) they become independent units—the *ribs*—which articulate with the vertebral column. In other regions they remain stunted and, almost unrecognisable in form, become fused with the vertebræ. Originally protective in function, in higher forms they also act as levers which play an important part in the movements of respiration.

Structure of a vertebra (fig. 263).—The body of a vertebra is composed of

spongy substance covered by a thin coating of compact bone, which presents numerous orifices for the passage of vessels; the interior of the body is traversed by one or two large canals, for the transmission of veins, which converge towards the large aperture on the posterior surface of the body. In the vertebral arch and the processes projecting from it the compact substance is thicker than it is in the body.

FIG. 263.—A median sagittal section through a lumbar vertebra.



THE INDIVIDUAL VERTEBRÆ

In the light of this description of a typical vertebra it is now possible to study the individual vertebræ of the human vertebral column, and observe how the essential features are modified in the different regions. In each region the vertebræ exhibit certain group characters, but atypical characters make their appearance at the upper and lower limits of each region for the purpose of adapting the vertebræ concerned to their neighbours.

In man the cervical vertebræ are seven in number; the thoracic, twelve; the lumbar, five; the sacral, five; and the coccygeal, four; making a total of thirty-three. The cervical, thoracic and lumbar vertebræ are separate bones throughout life and are therefore known as the *movable vertebræ*; the sacral and coccygeal, on the other hand, are termed *fixed vertebræ*, because, owing to the necessity for stability in this part of the column in man, they are united in the adult to form two bones, viz. the *sacrum* and the *coccyx.*

THE CERVICAL VERTEBRÆ [VERTEBRÆ CERVICALES]

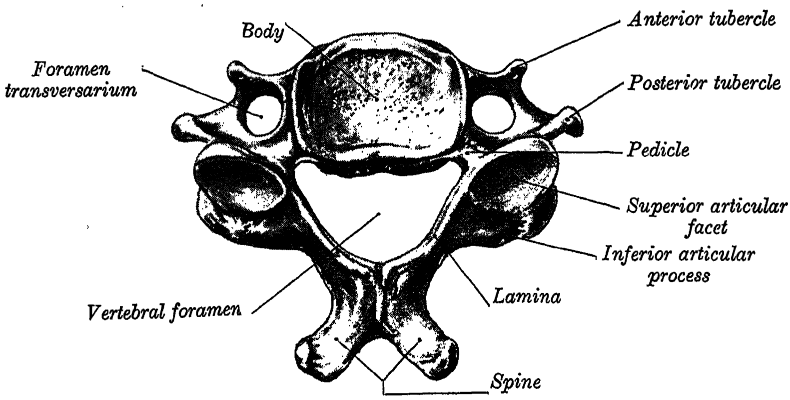
The cervical vertebræ (figs. 264, 270), seven in number, are the smallest of the movable vertebræ and can be identified easily owing to the peculiarity of their transverse processes, each of which is perforated by a foramen. The first, second and seventh cervical vertebræ present special distinguishing features, but the remaining four conform to a common type.

A typical cervical vertebra.—General features.—The body is small and is broader from side to side than from before backwards. The *vertebral foramen* is large in proportion to the size of the body and it is triangular in outline. These two features are accounted for, in part, by the direction of the *pedicles*, which project laterally as well as backwards (fig. 264). The superior and inferior vertebral notches are almost equal, for the pedicle is attached to the body nearly midway between its upper and lower borders. The *laminæ* are relatively long and narrow, and are thinner above than below. The *spine* (*spinous process*) is short and bifid and its terminal tubercles are often unequal in size. The *superior* and *inferior articular processes* form an *articular pillar*, which projects laterally at the unction of the pedicle and lamina. The *transverse process* is pierced by the *foramen transversarium* (fig. 264). It consists of an anterior and a posterior root, connected to each other on the lateral side of the foramen transversarium by a bar of bone, often termed the *costotransverse bar.* The anterior root and the costotransverse bar are homo-

logous with the rib in the thoracic region; the posterior root is the homologue of the thoracic transverse process.

Particular features.—The *anterior surface of the body* is convex from side to side, and its upper and lower borders give attachment to the fibres of the anterior longitudinal ligament. On each side of the ligament a slight depression gives attachment to fibres of the vertical portion of the longus cervicis (longus colli) muscle. The *posterior surface* is flattened and presents near its centre two or more vascular foramina, which transmit the basivertebral veins. Its upper and lower borders give attachment to the posterior longitudinal ligament. The *superior surface* is concave transversely and has an upwardly projecting lip on each side

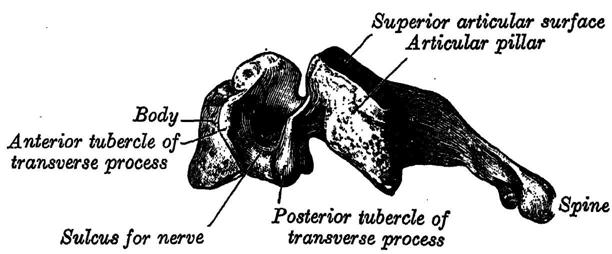
FIG. 264.—A typical cervical vertebra. Superior aspect.



(fig. 270); its anterior border may be slightly bevelled. The inferior surface is saddle-shaped, being convex from side to side and concave from before backwards. A small synovial joint is present on each side between the bevelled lateral border and the projecting lip of the upper surface of the vertebra below. The anterior border of the lower surface projects downwards and hides the intervertebral disc. The upper borders of the laminæ and the lower part of their anterior surfaces give attachment to the ligamenta flava. The spines give attachment to the ligamentum nuchæ and to a number of the deep muscles of the back of the neck, viz. semispinalis thoracis, multifidus, interspinales, spinalis cervicis and semispinalis cervicis.

The articular pillars of the third and fourth cervical vertebræ are grooved on their lateral aspects by the posterior primary rami of the third and fourth cervical nerves, which pass

FIG. 265.—A typical cervical vertebra. Left lateral aspect.



backwards across them.* The superior articular facets are flat and oval in outline; they are directed backwards and upwards. The inferior articular facets, similar in shape, are directed forwards and downwards. The foramen transversarium transmits the vertebral artery and veins and a plexus of sympathetic nerve fibres. The anterior root of the transverse process ends in a rough tubercle, which gives attachment to the scalenus anterior, the longus capitis and the oblique portions of the longus cervicis (longus colli) muscles. The anterior tubercle of the transverse process of the sixth cervical vertebra is enlarged and lies posterior to the common carotid artery, which can be compressed against it. It is therefore termed the *carotid tubercle*. The *costotransverse bar* is oblique in the third cervical vertebra, passing downwards, backwards and laterally; in the fourth also it is oblique, but it is slightly grooved by the emerging anterior primary ramus of the fourth cervical nerve. In the fifth the groove is deeper, and in the sixth it is conspicuously wide and

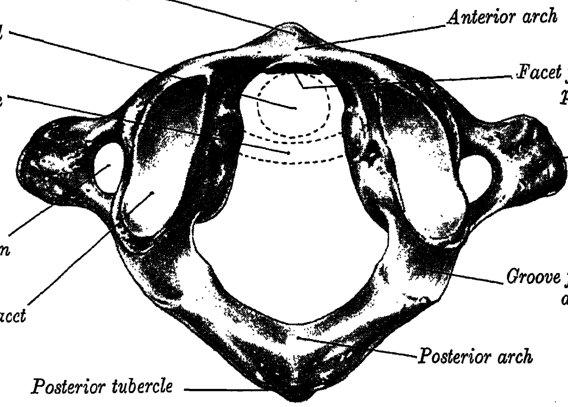
* F. Wood Jones, *Journal of Anatomy and Physiology*, vol. xlvi., 1911.

shallow. The posterior root of the transverse process terminates laterally in a rounded tubercle, which lies lateral to the anterior tubercle and at a lower level in all except the sixth, in which the two tubercles lie approximately on the same plane.

The posterior tubercles give attachment to a number of muscles, including levator scapulæ, scalenus medius (which extends forwards on to the costotransverse bar), scalenus posterior, splenius cervicis, longissimus cervicis and costocervicalis (iliocostalis cervicis).

The first cervical vertebra.—General features: **The first cervical vertebra** (fig. 266) is named the **Atlas,** because it supports the globe of the head. It differs from all the other vertebræ in having no body, and this is due to the fact that the centrum (p. 225) of the atlas has fused with the centrum of the second cervical vertebra. In addition, it has no spine. The atlas consists of two bulky *lateral masses,* connected to each other in front by a short *anterior arch,* and behind by a long, curved, *posterior arch.* It therefore forms a ring of bone. When the atlas and the second cervical vertebra are articulated together, an upward projection from the latter, which is termed the odontoid process and is the centrum of the atlas, comes into position behind the anterior arch, and the resemblance to a vertebra is restored (fig. 266).

FIG. 266.—The first cervical vertebra, or atlas. Superior aspect.



The *anterior arch* is slightly curved from side to side, with a forward convexity which is accentuated by the presence of a roughened, *anterior tubercle.* Its posterior surface is marked by a median, oval or circular facet, which articulates with the front of the odontoid process (dens). The *lateral mass* is set obliquely, and its long axis runs forwards and medially. Its upper surface forms an elongated, concave facet for articulation with the prominent condyle of the occipital bone of the skull. The inferior surface bears a nearly circular facet, flattened or gently concave, for articulation with the superior facets of the second cervical vertebra. The *posterior arch* forms about two-fifths of the ring. Its upper surface shows a wide groove immediately behind the lateral mass, and its spine is represented by a small, rough *posterior tubercle.* The *transverse process* is unusually long (fig. 270) and, as a result, the width of the atlas, measured from tip to tip of its transverse processes, greatly exceeds that of any other cervical vertebra, except the seventh. The length and strength of these transverse processes enables them to function as adequate levers for the rotatory movements of the head, which are effected by the rotation of the skull and the atlas around the pivot provided by the odontoid process of the second cervical vertebra.

Particular features.—The *anterior tubercle* gives attachment to the anterior longitudinal ligament in the median plane: its lateral aspect provides insertion for the upper oblique portion of the longus cervicis (longus colli) muscle. The upper and lower borders of the *anterior arch* give attachment respectively to the anterior atlanto-occipital membrane and the lateral fibres of the anterior longitudinal ligament (anterior atlanto-axial membrane). The superior articular facet of the *lateral mass* is directed upwards and medially and is admirably adapted to the nodding movements of the head, which occur at the atlanto-occipital joints. It is usually constricted near its middle and may be subdivided into two

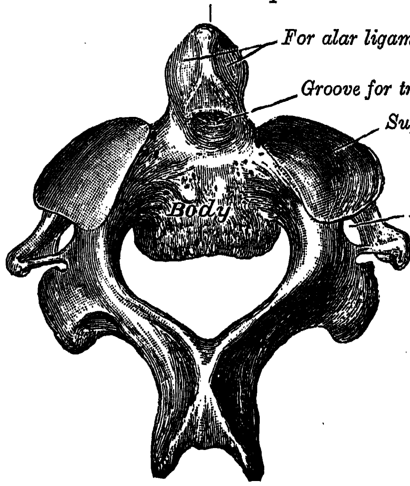
separate areas. Its margins give attachment to the articular capsule of the atlanto-occipital joint. The inferior articular facet is directed downwards, medially and slightly backwards; its margins give attachment to the articular capsule of the atlanto-axial joint. The medial aspect of the lateral mass presents a small roughened tubercle for the attachment of the transverse ligament of the atlas (fig. 512), which passes behind the odontoid process (dens) and helps to retain it in place. This ligament divides the ring of the atlas into an anterior, smaller part, which contains the odontoid process (fig. 266), and a posterior, larger part, which transmits the spinal cord and its membranes. The anterior aspect of the lateral mass gives origin to the rectus capitis anterior muscle.

The *posterior tubercle* gives attachment in the median plane to the ligamentum nuchæ, and, on each side, to the rectus capitis posterior minor. Its small size prevents it from interfering with the nodding movements of the head. The upper surface of the *posterior arch* is grooved anteriorly, where it is overhung on each side by the lateral mass. The groove transmits the vertebral artery, which winds backwards and medially round the posterior aspect of the lateral mass (fig. 514). Occasionally the groove for the vertebral artery is converted into a foramen by a bony spicule which arches backwards from the posterior part of the upper surface of the lateral mass. The first cervical nerve, as it emerges from the vertebral canal, intervenes between the vertebral artery and its groove (fig. 514). Behind the groove, on each side, the upper border of the posterior arch gives attachment to the posterior atlanto-occipital membrane; its lower border gives attachment to the highest pair of ligamenta flava.

The length of the *transverse process* and its functional significance have already been considered. Its down-turned extremity, which shows no differentiation into anterior and posterior tubercles, may be felt through the skin between the tip of the mastoid process and the angle of the mandible. Its recognition is not easy, for it lies deeply under cover of the parotid gland. Numerous muscles are attached to the process. The rectus capitis lateralis, anteriorly, and the superior oblique muscle of the head, posteriorly, arise from its upper surface: the levator scapulæ takes origin from its lateral margin and lower border, concealing the uppermost slip of insertion of the splenius cervicis and itself often hidden by the origin of the scalenus medius. A small, often imperceptible, tubercle may be present on the anterior surface of the lateral mass; it represents the anterior tubercle of the typical transverse process, so that the transverse process of the atlas corresponds to the posterior root and the costotransverse bar of the other cervical vertebræ. The anterior primary ramus of the first cervical nerve runs forwards on the lateral surface of the lateral mass and then turns downwards across the anterior surface of the transverse process. As it does so it is covered by the internal jugular vein, which is crossed in this situation by the accessory nerve and the occipital artery.

The **second cervical vertebra**.—General features: The second cervical vertebra, which is named the **Axis** (figs. 267, 268), provides the pivot upon which

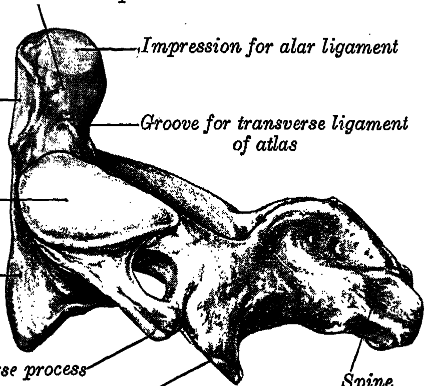
FIG. 267.—The second cervical vertebra, or axis. Posterosuperior aspect.



the atlas, and with it the skull, rotate. It can be distinguished easily from the other vertebræ by means of the strong, toothlike process, named the *odontoid process*

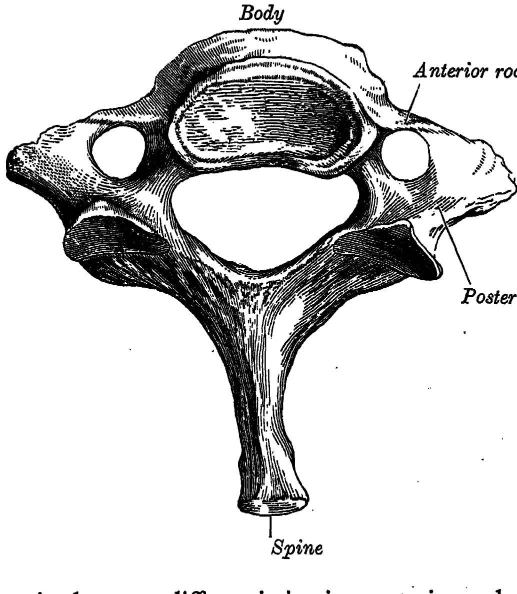
(dens), which projects upwards from the *body*. The process bears on its anterior surface a small oval facet for articulation with the facet on the posterior surface of the anterior arch of the atlas, and posteriorly it is grooved slightly by a ligament which helps to retain it in position (fig. 267). On each side a large, oval or circular facet is borne on the lateral part of the upper surface of the body and the

FIG. 268.—The second cervical vertebra, or axis. Left lateral aspect.



adjoining part of the pedicle for articulation with the inferior facet of the lateral mass of the atlas. The *laminæ* are thick and strong and the vertebral foramen is large and roomy. The *spine* is large and very strong, for it has to provide attachments not only for muscles which extend the neck but also for muscles which retract the head and rotate it from side to side. The *transverse process*, on the other hand, is very

FIG. 269.—The seventh cervical vertebra. Superior aspect.

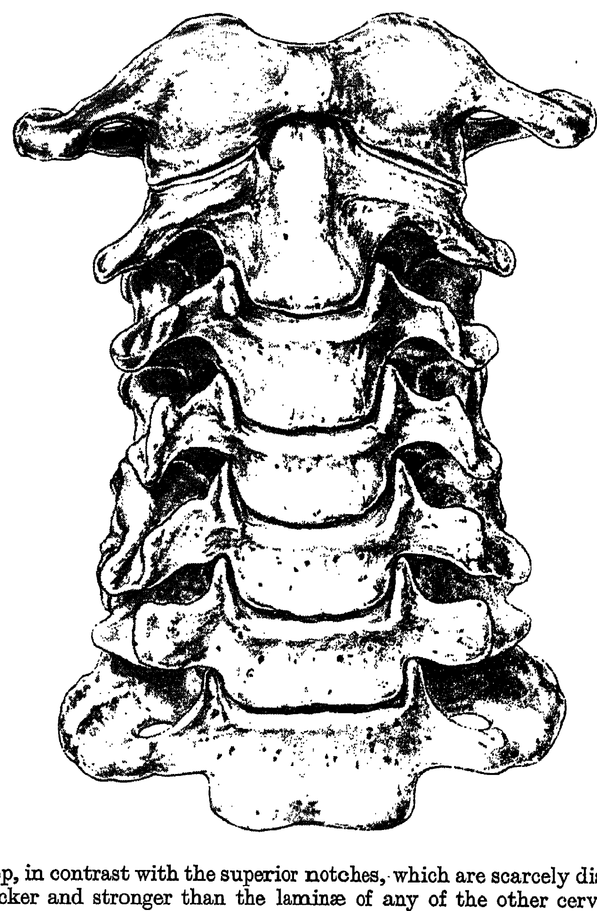


small and its blunt tip shows no differentiation into anterior and posterior tubercles. The foramen transversarium is directed upwards and laterally. The *inferior articular facets* look downwards and forwards, as they do in the typical cervical vertebræ.

Particular features.—The *odontoid process* is conical in shape and about 1·5 cm. long; it is constricted below, where it lies in contact posteriorly with the transverse ligament of

the atlas. A bursa is usually interposed between the bone and the ligament. The apex is pointed and gives attachment to the apical ligament (p. 444). Below the apex the sides of the process are flattened, where the alar ligaments are attached (fig. 267). In structure the odontoid process is composed of more compact bone than the body. The upper surface of the *body* is obscured by the odontoid process and the superior articular facets. Its anterior surface presents a hollowed out impression on each side of the median plane for the insertion of vertical fibres of the longus cervicis (longus colli) muscle. The lower border gives attachment to the anterior longitudinal ligament, and its downward projection is a characteristic feature of the axis. Posteriorly the lower border of the body gives attachment to the posterior longitudinal ligament and to the membrana tectoria, which represents its upward continuation to the occipital bone (p. 444). The *pedicles* are stout and the inferior vertebral

FIG. 270.—The cervical vertebræ. Anterior aspect.



notches are deep, in contrast with the superior notches, which are scarcely discernible. The *laminæ* are thicker and stronger than the laminæ of any of the other cervical vertebræ; they provide attachment for the ligamenta flava. The coarse, strong *spine* gives origin to the inferior oblique muscle, which arises from a rough impression on its lateral aspect, and also to the rectus capitis posterior major, which arises from its posterior border. The wide gap at its extremity gives attachment to the ligamentum nuchæ. In addition it receives the insertions of portions of the semispinalis cervicis, spinalis cervicis, interspinalis and multifidus. The *foramen transversarium* is directed upwards and laterally as, owing to the difference in length between the transverse process of the axis and that of the atlas, the vertebral artery must deviate in a lateral direction after leaving the axis. The *transverse process* is small, and its anterior tubercle is situated at or near the point where the anterior part of the process reaches the body; in this respect it resembles the anterior tubercle of the transverse process of the atlas. Its extremity gives origin to the levator scapulæ and, more anteriorly, to the scalenus medius; more posteriorly, it gives insertion to the splenius cervicis. Intertransverse muscles (p. 550) also gain attachment to its upper and lower surfaces.

The seventh cervical vertebra.—General features: The seventh cervical vertebra (fig. 269) is named the *vertebra prominens* because of its long spine, the tip of which can be felt through the skin at the lower end of the nuchal

furrow. This process is thick and nearly horizontal in direction; it is not bifurcated but ends in a tubercle. The *transverse processes* are of considerable size and their posterior parts are large and prominent. The anterior parts are usually slender, but they may form separate bones, which are then known as *cervical ribs*. The *foramen transversarium* is relatively small; it is sometimes double, or it may be entirely absent.

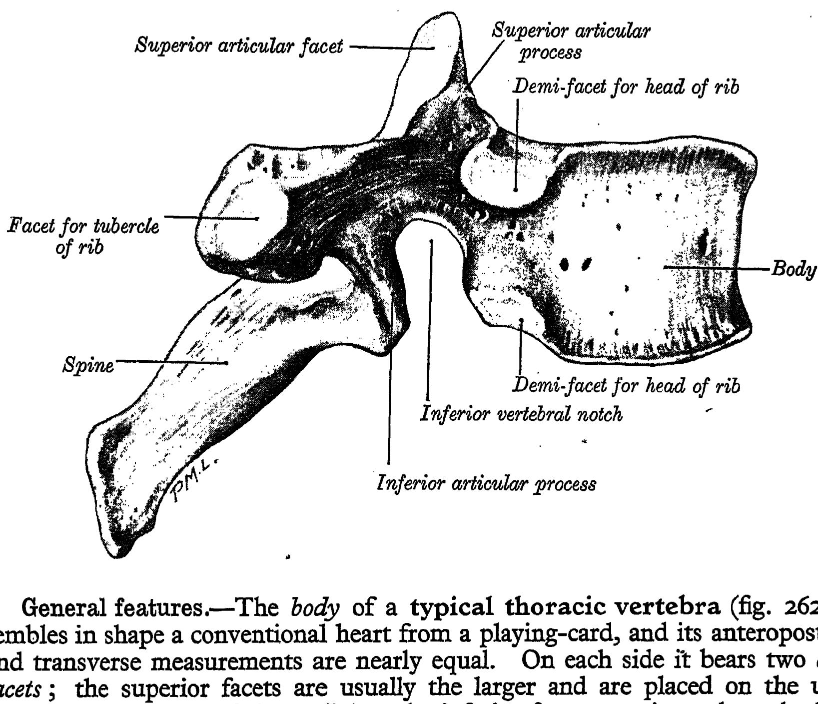
Particular features.—The tip of the spine gives attachment to the lower end of the ligamentum nuchæ, as well as to a number of muscles. These include the trapezius, rhomboideus minor, serratus posterior superior, splenius cervicis, semispinalis thoracis, spinalis cervicis, interspinales and multifidus. The *foramen transversarium* is traversed by an accessory vertebral vein or veins: it is traversed by the vertebral artery only on very rare occasions. The costotransverse bar of the *transverse process*, which shows a shallow groove for the anterior primary ramus of C. 7, is often partly deficient. The prominent posterior tubercle gives origin to the scalenus minimus, when it is present, and to the aponeurotic layer of fascia which covers the cervical dome of the pleura [suprapleural membrane]. Its lower border gives origin to the highest of the levatores costarum muscles.

THE THORACIC VERTEBRÆ [VERTEBRÆ THORACALES]

The **thoracic vertebræ** (figs. 262, 271, 272), twelve in number, show a gradual increase in size from above downwards. All are distinguished by the presence of facets on the sides of the bodies, and all but the last two (sometimes three) by facets on the transverse processes; the former articulate with the heads of the ribs and the latter with the tubercles of the ribs.

The first, ninth, tenth, eleventh and twelfth thoracic vertebræ present certain peculiarities and must be considered separately. The others, although showing individual differences of a minor degree, conform to a common type.

FIG. 271.—A typical thoracic vertebra. Viewed from the right side.



General features.—The *body* of a **typical thoracic vertebra** (fig. 262) resembles in shape a conventional heart from a playing-card, and its anteroposterior and transverse measurements are nearly equal. On each side it bears two *costal facets*; the superior facets are usually the larger and are placed on the upper border near the root of the pedicle; the inferior facets are situated on the lower border of the body just in front of the inferior vertebral notch. The *vertebral foramen* is relatively small, and its circular outline may be associated with the fact that the *pedicles* show no lateral deviation as they pass backwards from the body. This accounts also for the shortness of the *laminæ*, which are broad and thick and overlap each other from above. The *spine* is long and is directed downwards and

backwards. The *superior articular processes* are thin plates of bone which project upwards at the junction of the laminæ and pedicles; their articular facets are almost flat and are directed backwards and a little laterally and upwards. The *inferior articular processes* are fused to the lateral ends of the laminæ; their articular facets are directed forwards and slightly downwards and medially. The *transverse process* is a substantial, club-shaped projection which springs from the vertebral arch at the junction of the lamina and pedicle. It is directed laterally and backwards and bears on its anterior aspect, near its extremity, a facet for articulation with the tubercle of the numerically corresponding rib.

The **first thoracic vertebra** is distinguished by the character of the upper facets on the sides of the body, which are circular in outline, as each articulates with the whole of the head of the first rib. The lower facets are small and semilunar in shape. The spine is thick, long and horizontal; it can be identified easily in the living subject, for it forms a visible projection below the spine of the vertebra prominens.

The **ninth thoracic vertebra** may possess all the features of a typical thoracic vertebra, but it often fails to articulate with the head of the tenth rib, and the lower facets on the body are then absent (fig. 272).

The **tenth thoracic vertebra** articulates with the head of the tenth rib only. The facet is placed at the upper border of the body and encroaches on the pedicle; it is usually incomplete but, when the tenth rib fails to articulate with the ninth thoracic vertebra, it is complete and circular in outline. The transverse process may, or may not, bear an articular facet for the tubercle of the tenth rib.

The **eleventh thoracic vertebra** articulates with the head of the eleventh rib only. The circular facet is placed close to the upper border of the body and extends backwards on to the lateral aspect of the pedicle. The transverse process is small but can be gripped between the finger and thumb; it is not marked by an articular facet.

The **twelfth thoracic vertebra** articulates with the head of the twelfth rib only. The facet, roughly circular in outline, lies below the upper border of the body and extends over the lateral aspect of the pedicle. The body is large and approximates closely to the lumbar type. The transverse process is small and insignificant and is not marked by an articular facet; it presents superior, lateral and inferior tubercles. The inferior articular processes are turned laterally and the articular facets are convex from side to side, like those of a lumbar vertebra.

Particular features of the thoracic vertebræ.—The bodies of the upper thoracic vertebræ show a gradual transition from the cervical to the thoracic type, while the bodies of the lower thoracic vertebræ show a similar transition from the thoracic to the lumbar type. The body of T. 1 is cervical in form, and its transverse is nearly twice as great as its anteroposterior measurement. The body of T. 2 retains the cervical type, but its breadth is less and the disproportion between its two measurements is diminished. The body of T. 3 is actually the smallest of the thoracic bodies, but its anterior aspect, instead of being flattened like the bodies of T. 1 and T. 2, is rounded off and is convex forwards from side to side. From this point the bodies gradually increase in size and, owing to an increase in the anteroposterior measurement, that of T. 4 is typically heart-shaped. The bodies of T. 5 to T. 8 show a gradual increase in the anteroposterior measurement while the transverse measurement shows little alteration. These four vertebræ, when seen on transverse section, are asymmetrical, for the left side of each body shows a flattening produced by the pressure of the descending thoracic aorta. The remaining vertebræ increase in size more rapidly, the increase affecting all the measurements of the body, so that T. 12 approximates closely to the shape of a typical lumbar vertebra.

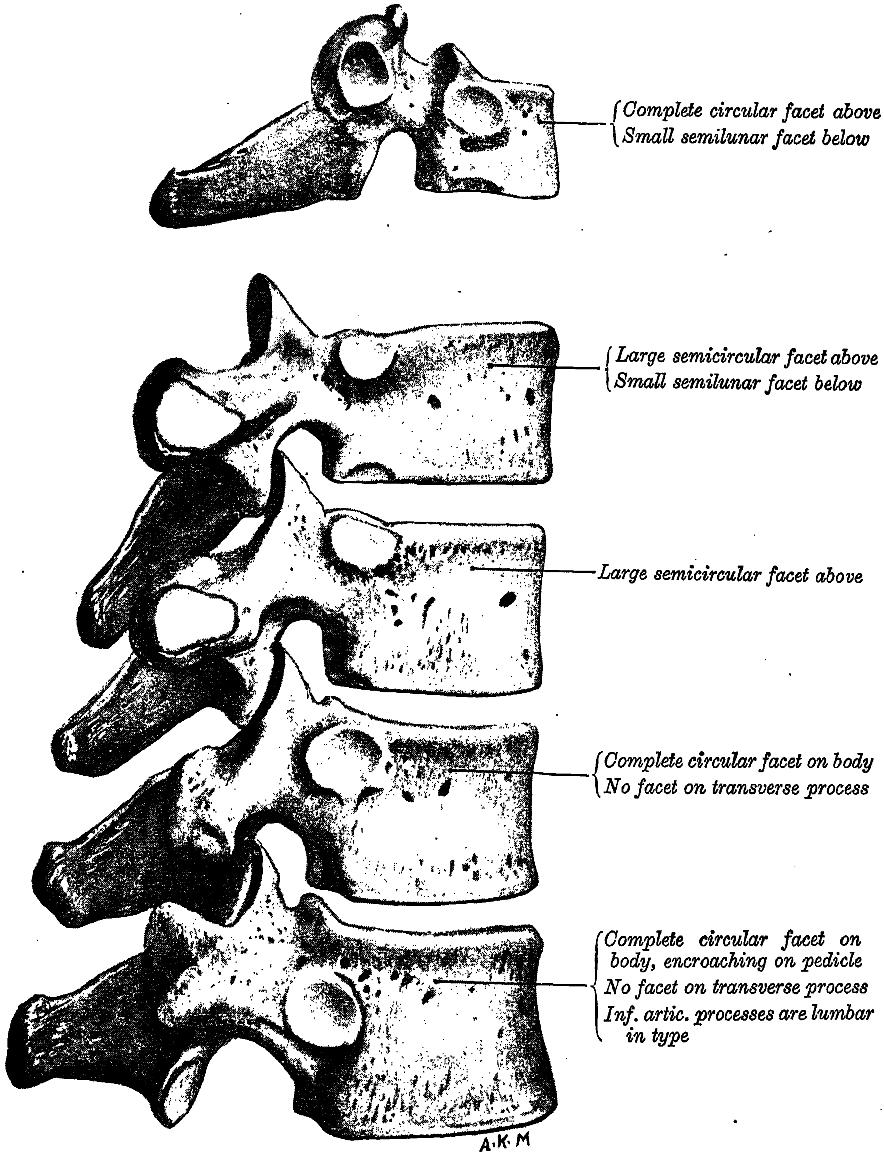
The upper and lower borders of the bodies in front and behind give attachment to the anterior and posterior longitudinal ligaments, respectively; and the margins of the costal facets give attachment to the capsular and radiate ligaments of the joints of the heads of the ribs. The longus cervicis (longus colli) muscle arises from the bodies of the first three thoracic vertebræ, lateral to the anterior longitudinal ligament. The psoas major and minor muscles arise from the lateral aspect of the twelfth thoracic vertebra near its lower border.

The *pedicles* increase in thickness from above downwards. The *superior vertebral notch* is scarcely recognisable except in the first thoracic vertebra, but the *inferior notch* is deep and conspicuous. The upper borders of the *laminæ* and the lower parts of their anterior surfaces serve for the attachment of the ligamenta flava; their dorsal aspects give insertion to the rotatores muscles.

The *transverse processes* gradually diminish in length from above downwards. In the upper six (sometimes five) the costal facets are concave and face forwards and laterally;

in the others the facets are flattened and face upwards, laterally, and slightly forwards. The tuberculated extremity of the process gives attachment to the lateral costotransverse ligament (ligament of the tubercle of the rib): its lower border, to the superior (anterior) costotransverse ligament: its anterior surface, medial to the facet, to the inferior costotransverse ligament (ligament of the neck of the rib): and its base to the posterior costotransverse ligament. In addition, the upper and lower borders of the transverse process

FIG. 272.—The first, ninth, tenth, eleventh and twelfth thoracic vertebræ. Right lateral aspect.



provide attachment for intertransverse muscles or their fibrous vestiges, and the posterior surface for the deep muscles of the back—the levator costæ arising from the dorsal aspect of the tuberculated extremity under cover of the longer muscles.

The *spines* overlap from the fifth to the eighth, which are the longest and most nearly vertical of the thoracic spines. Above and below they are less oblique in direction.* They

* In quadrupeds the majority of the spines of the thoracic vertebræ project dorsally and caudally, while those in the lumbar region are directed dorsally and headwards. The change in inclination is effected in one of the lower thoracic vertebræ, the spine of which points almost straight dorsally. This vertebra is known as the *anticlinal*, and in man its representative is the eleventh thoracic.

give attachment to the supraspinous and interspinous ligaments, and to the trapezius, rhomboideus major and minor, latissimus dorsi, the serratus posterior superior and inferior, and many of the deep muscles of the back.

The **first thoracic vertebra** resembles a cervical vertebra in the shape of its body. In addition, the posterolateral parts of its upper border are raised, as they are in the cervical region, and this projection forms the anterior border of the superior vertebral notch, *which is a distinctive feature of this vertebra.* The upper facet on the side of the body is not always complete, as the head of the first rib often articulates with the intervertebral disc between the seventh cervical and the first thoracic vertebræ. Immediately below the facet there is frequently a small, deep depression in the bone.

In the **eleventh** and **twelfth thoracic vertebræ** the spines are characteristically triangular, with blunted apices. In each case, the lower border of the spine is horizontal, or nearly so, and the upper border is oblique. In the region of the transverse process of the twelfth thoracic vertebra three little tubercles can be distinguished. Of these the *superior* is the largest and juts upwards. It corresponds to the mamillary process of a lumbar vertebra, but it is not so closely connected with the superior articular process. The *lateral tubercle* is small and corresponds to the true transverse process. The *inferior tubercle,* directed downwards, corresponds to the accessory process of a lumbar vertebra.

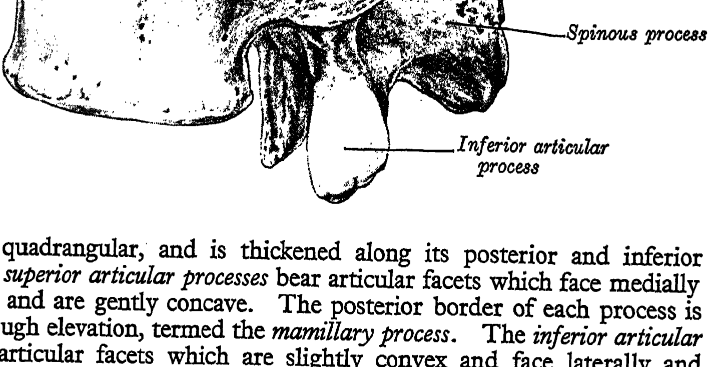
In distinguishing between these two vertebræ the student should be guided by (1) the character of the inferior articular processes; (2) the size and character of the transverse process; and (3) the distance between the costal facet and the upper border of the vertebra (p. 214).

THE LUMBAR VERTEBRÆ [VERTEBRÆ LUMBALES]

General features.—The **lumbar vertebræ** (figs. 273–275), five in number, can be distinguished from the other vertebræ by their great size and by the absence of costal facets on the sides of the bodies.

The *body* is large, wider from side to side than from before backwards, and a little deeper in front than behind. The *vertebral foramen* is triangular in shape, larger than in the thoracic region but smaller than in the cervical region. The shape is accounted for by the shortness of the pedicles and the direction of the laminæ, which pass backwards and medially. The *spine* projects almost horizontally

FIG. 273.—A lumbar vertebra. Left lateral aspect.



backwards, is quadrangular, and is thickened along its posterior and inferior borders. The *superior articular processes* bear articular facets which face medially and backwards and are gently concave. The posterior border of each process is marked by a rough elevation, termed the *mamillary process.* The *inferior articular processes* bear articular facets which are slightly convex and face laterally and forwards. The *transverse processes* are thin and elongated, with the exception of those of the fifth lumbar vertebra, which are strong and substantial. A small, rough elevation marks the postero-inferior aspect of the root of each transverse process and is termed the *accessory process.*

The **fifth lumbar vertebra** (fig. 275) can be distinguished by the fact that its strong *transverse process* is connected to the *whole of the lateral surface of the pedicle*

and encroaches on the side of the body. In addition, its body is usually deeper in front than behind, a condition which is associated with the prominence of the sacrovertebral angle.

FIG. 274.—A lumbar vertebra. Posterosuperior aspect.

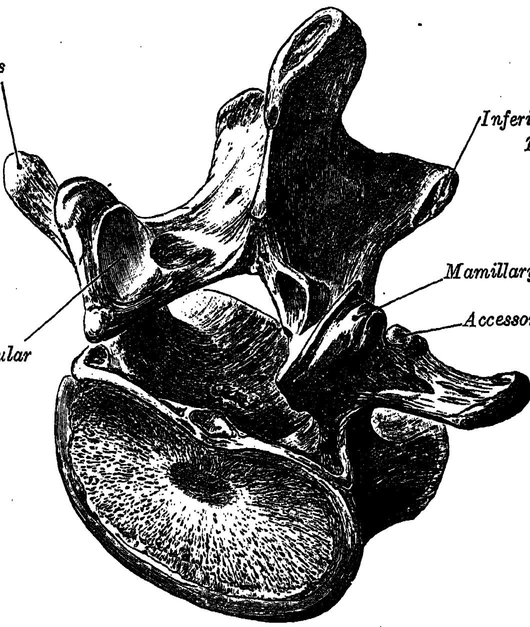
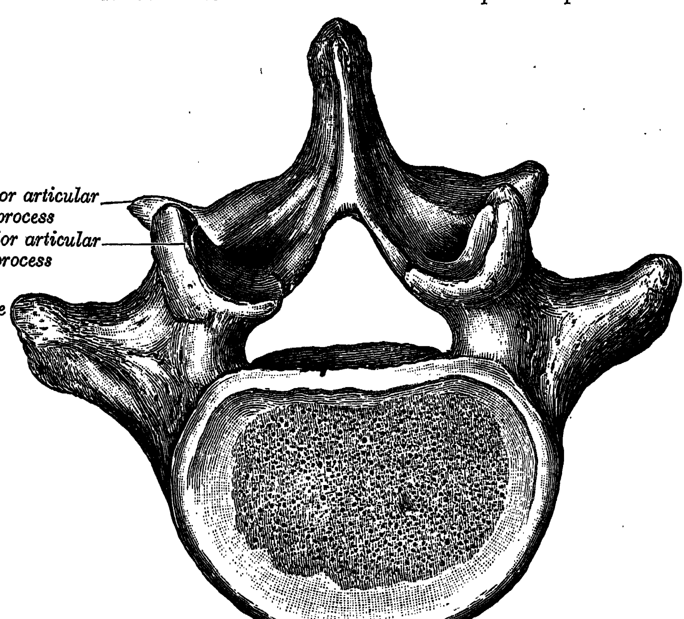


FIG. 275.—The fifth lumbar vertebra. Superior aspect.



Particular features.—The upper and lower borders of the *bodies* in front and behind give attachment to the anterior and posterior longitudinal ligaments. Lateral to the anterior longitudinal ligament, the bodies of the upper lumbar vertebræ (three on the right side; two on the left) give origin to the crura of the diaphragm. Behind the line of the crus the psoas major arises from the bodies of all the lumbar vertebræ. This muscle throws tendinous arches across the sides of the bodies to protect the lumbar vessels. The *vertebral foramen* of the first lumbar vertebra contains the lower part of the spinal cord—the conus medullaris;

the lower foramina contain the cauda equina and the spinal meninges. The *pedicle* is strong, and springs from the posterolateral aspect of the body just below its upper border. The *superior vertebral notch,* though shallow, is easily recognisable : the *inferior notch* is of considerable depth. The *laminæ* are broad, short and strong, but they do not overlap one another to the same extent as they do in the thoracic region. They give attachment to the ligamenta flava. The *spines* provide attachment for the posterior lamella of the lumbar fascia, the sacrospinalis, the spinalis thoracis, the multifidus, the interspinal muscles and ligaments and the supraspinous ligaments. The spine of the fifth lumbar vertebra is the least substantial and its extremity is more or less rounded and down-turned. The *superior articular processes* are wider apart than the *inferior* in the upper lumbar region, but the difference is very slight in the fourth, and in the fifth the two measurements are approximately equal. The articular facets are so shaped that, while they permit of flexion and extension, they prevent rotation of the lumbar vertebræ. The *transverse processes,* with the exception of the fifth, are not so strongly built as the other parts of the lumbar vertebræ. They increase in length from the first to the third—which is the longest of all the transverse processes—and then become shorter. A faint, vertical ridge marks the anterior surface of the transverse process nearer the tip than the root. It gives attachment to the anterior layer of the lumbar fascia and separates the surface into a medial area for the attachment of the psoas major, and a lateral area for the quadratus lumborum. The tip of the process gives attachment to the middle layer of the lumbar fascia, but, in addition, the tip of the first gives attachment to the medial and lateral arcuate ligaments (lumbocostal arches) and the tip of the fifth to the iliolumbar ligament. The posterior surfaces of the transverse processes are covered by the deep muscles of the back and give origin to fibres of the longissimus thoracis (longissimus dorsi) muscle. The upper and lower borders of the process give attachment to lateral intertransverse muscles. The *mamillary process* is homologous with the superior tubercle in the twelfth thoracic vertebra. It gives attachment to the multifidus and to the medial intertransverse muscle. The *accessory process* * varies in prominence and may be difficult to identify. It gives attachment to the medial intertransverse muscle. The *costal element* is incorporated in the transverse process (fig. 113).

THE SACRUM [OS SACRUM]

General features.—The **sacrum** (figs. 276–280) is a large bone, triangular in shape, formed by the fusion of the five sacral vertebræ. It is situated at the upper and posterior part of the pelvic cavity, where it is inserted like a wedge between the two hip-bones. Its narrow, blunted *apex* is at the inferior end of the bone and articulates with the coccyx. At the opposite end the wide *base* articulates with the fifth lumbar vertebra, with which it forms the *sacrovertebral angle.* The bone is placed very obliquely and is curved longitudinally so that its dorsal surface is convex and its ventral surface is concave (fig. 278). This ventral concavity serves to increase the capacity of the true pelvis. In addition to a base and an apex the sacrum possesses *dorsal, pelvic,* and *lateral surfaces* and encloses a bony *canal.*

In the child the individual sacral vertebræ are connected by cartilage and can be separated by maceration. The adult bone shows many signs of its vertebral constitution, especially on its basal aspect.

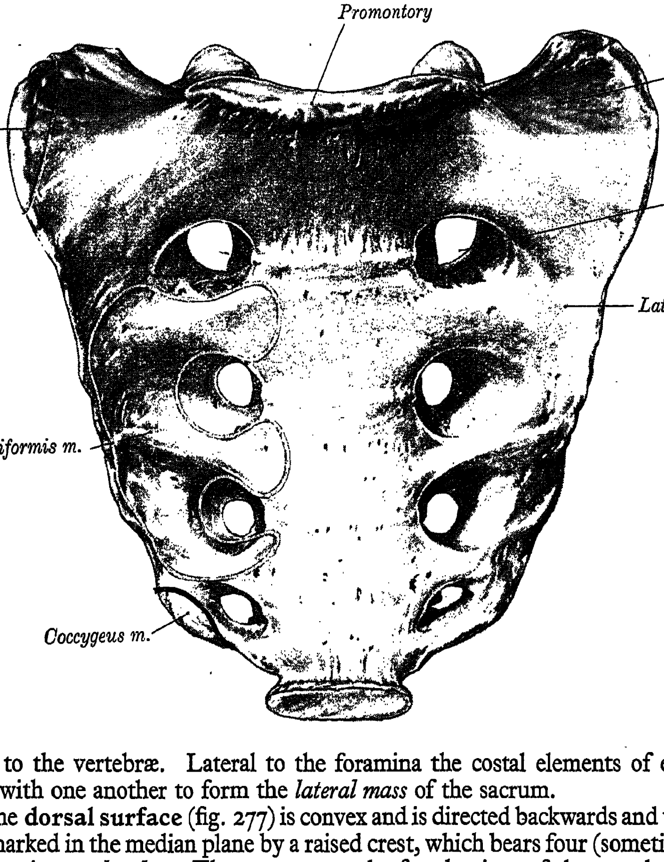
The **base** (fig. 279) is formed by the upper surface of the *first sacral vertebra* and presents all the features of a typical vertebra in a slightly modified form. The *body* is large and much wider from side to side than from before backwards. Its anterior projecting edge is named the *sacral promontory.* The vertebral foramen is triangular, and its shape is explained by the fact that the *pedicles* are short, widely separated, and face backwards and laterally. The *laminæ* are very oblique and incline downwards, medially and backwards. Where they meet, the *spine* is represented by a spinous tubercle. The *superior articular processes* project upwards and bear concave articular facets which face medially and backwards to articulate with the inferior articular processes of the fifth lumbar vertebræ. The posterior part of each process projects backwards, and its lateral aspect bears a roughened area which corresponds to the mamillary process of a lumbar vertebra. The region of the *transverse process* shows important modifications. A broad, sloping mass of bone projects from the lateral side of the body, pedicle and superior articular process;

* The mamillary and accessory processes " are merely muscular processes which, represented and conjoined in the thoracic region, become separated in the lumbar region by the passage of the internal (medial) branch of the posterior division (posterior primary ramus) of the lower thoracic and lumbar nerves between them." (F. Wood Jones, *Journal of Anatomy and Physiology,* vol. xlvii., p. 118.)

a feature which is not found in any of the other vertebræ, although it is foreshadowed in the fifth lumbar vertebra. It is formed by the transverse process and the costal element fused to each other and to the rest of the vertebra, and forms the upper surface of the *lateral mass* of the sacrum.

The **pelvic surface** of the sacrum is concave and is directed downwards and forwards. It is marked by four pairs of *anterior sacral foramina*, which communicate through the intervertebral foramina with the sacral canal. They transmit the anterior primary rami of the sacral nerves. The large area which lies between the foramina of the right and left sides is formed by the flattened anterior surfaces of the bodies of the sacral vertebræ, and the lines of fusion of contiguous vertebræ are clearly visible as four raised *transverse ridges*. The bars of bone which separate the foramina from one another on each side represent the *costal elements*, which are

FIG. 276.—The sacrum. Pelvic surface.



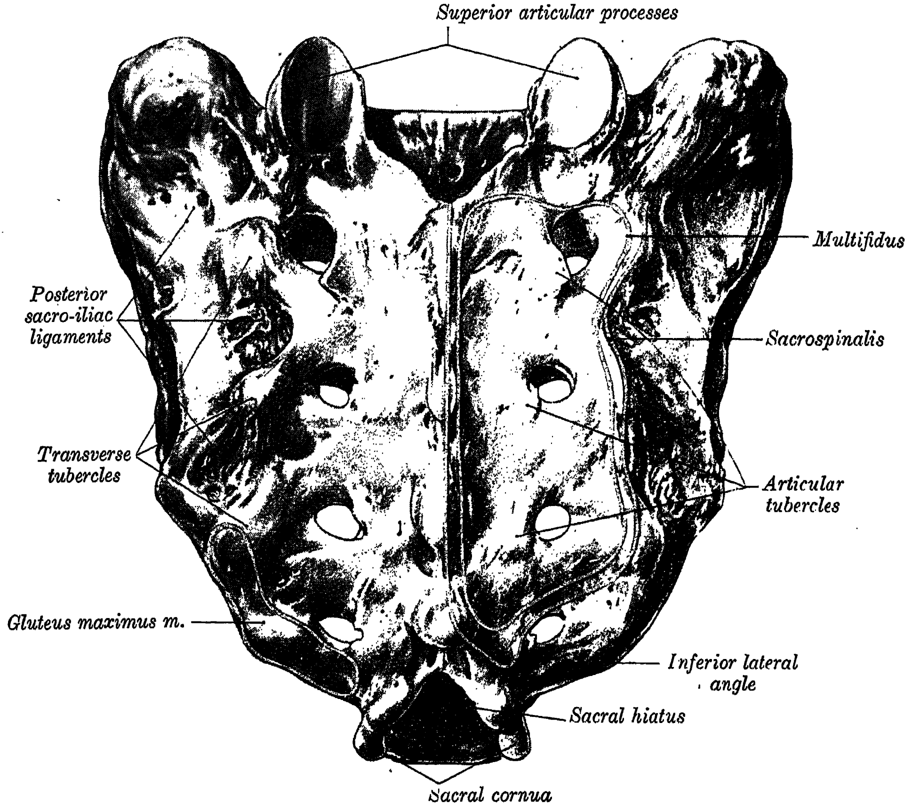
fused to the vertebræ. Lateral to the foramina the costal elements of each side unite with one another to form the *lateral mass* of the sacrum.

The **dorsal surface** (fig. 277) is convex and is directed backwards and upwards. It is marked in the median plane by a raised crest, which bears four (sometimes only three) *spinous tubercles*. These represent the fused spines of the sacral vertebræ. Below the fourth spinous tubercle there is a ∩-shaped gap in the posterior wall of the sacral canal, termed the *sacral hiatus*. This gap is produced by the failure of the laminæ of the fifth sacral vertebræ to meet in the median plane, and, as a result, the posterior aspect of the body of that vertebra is exposed on the dorsal surface of the sacrum. Lateral to the median crest, the posterior surface is formed by the fused *laminæ*. Lateral to this area the dorsal surface of the sacrum presents on each side four *posterior sacral foramina*. Like the anterior foramina they communicate with the sacral canal through the intervertebral foramina; and each transmits the posterior primary ramus of a sacral nerve. Medial to the foramina, and in line with the superior articular process of the first sacral vertebra, the bone is marked on each side by a row of four small tubercles, which represent contiguous articular processes fused together. The inferior articular processes of the fifth sacral vertebra are free and project downwards at the sides of the sacral hiatus. They are termed the *sacral cornua* and are connected to the cornua of the coccyx by ligaments, termed

the intercornual ligaments. The roughened area to the lateral side of the posterior sacral foramina is formed by the fused transverse processes and presents a row of *transverse tubercles*.

The **lateral surface** (fig. 278) of the sacrum is formed by the fused transverse processes and costal elements. It is wide above but rapidly diminishes in breadth in its lower part. The broad, upper part bears an ear-shaped surface, termed the *auricular surface*, for articulation with the ilium, and the area behind it is rough and deeply pitted for the attachment of ligaments. In order to ensure the stability of the body in the erect posture, the sacro-iliac joint, through which one half of the weight of the trunk is transmitted to the lower limb, must provide a good bearing surface. This is obtained by the fusion of the sacral vertebræ and by the persistence of substantial portions of the costal elements. The auricular surface is borne by the costal elements and is shaped like the inverted letter L. The horizontal limb

FIG. 277.—The sacrum. Dorsal surface.



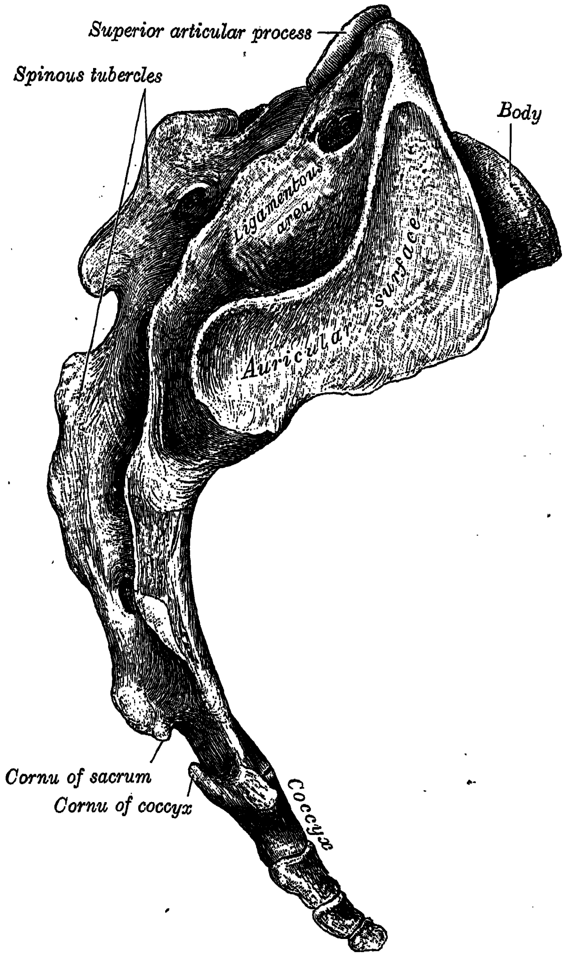
is the shorter and is restricted to the first sacral vertebra: the vertical limb extends downwards to the lower limit of the second or to the middle of the third sacral vertebra. The lower part of the lateral surface takes no part in the transmission of the weight of the body and is consequently reduced in breadth. At its lower end it bends or curves medially to reach the side of the body of the fifth sacral vertebra. The point at which the change of direction occurs is termed the *inferior lateral angle*. Below the angle the lateral surface forms a thin border.

The **apex** of the sacrum is formed by the inferior surface of the body of the fifth sacral vertebra and bears an oval facet for articulation with the coccyx.

The **sacral canal** (fig. 280) is formed by the vertebral foramina of the sacral vertebræ and is triangular on transverse section. Its upper opening, seen on the basal surface, appears to be set obliquely but, owing to the inclination of the sacrum, it is directed upwards in the living subject. The lateral wall of the canal presents four intervertebral foramina, through which the canal is connected with both the anterior and the posterior sacral foramina. The lower opening is the *sacral hiatus*.

Particular features.—The anterior and posterior parts of the *body of the first sacral vertebra* give attachment to the lowest fibres of the anterior and posterior longitudinal ligaments respectively. The upper borders of the *laminæ* of the first sacral vertebra give attachment to the lowest pair of ligamenta flava. The *upper surface of the lateral mass* is smooth and slightly concave in its medial part but is irregularly roughened in its lateral part. It is covered almost entirely by the psoas major muscle. The smooth area is marked by an oblique, shallow groove which lodges the lumbosacral trunk. The rough area gives attachment to the lumbosacral ligament, which lies on the lateral side of the fifth lumbar nerve, and to the anterior ligament of the sacroiliac joint. The anterolateral part of the area gives origin to a portion of the iliacus muscle.

Fig. 278.—The sacrum and coccyx. Right lateral aspect.



The *pelvic surface* of the sacrum gives origin on each side to the piriformis muscle. This muscle arises from the anterior surface of the lateral mass opposite the second, third and fourth sacral vertebræ and from the anterior surfaces of the bars of bone which separate the anterior foramina. On emerging from the anterior sacral foramina the anterior primary rami of the first three sacral nerves pass at once on to the anterior surface of the muscle. Along the medial margins of the foramina, on each side, the sympathetic trunk descends in contact with the bone, and in the median plane the median sacral vessels form an intimate relation. Lateral to the foramina the lateral sacral vessels bear a variable relation to the bone. The anterior surfaces of the bodies of the first and second and part of the third sacral vertebra are covered with parietal peritoneum and crossed obliquely, to the left of the median plane, by the root of the pelvic mesocolon. The rectum lies in contact with the anterior surfaces of the bodies of the third, fourth and fifth sacral vertebræ, but the bifurcation of the superior rectal artery into right and left branches intervenes between it and the third sacral vertebra.

The *dorsal surface* of the sacrum is rough and irregular. The sacrospinalis arises by an elongated U-shaped origin from the spinous and transverse tubercles, and covers the multi-

fidus, which arises from the intervening area. The posterior primary rami of the upper three sacral nerves pierce these muscles after they emerge from the posterior sacral foramina. It not infrequently happens that the laminæ of the fourth sacral vertebra fail to meet in the median plane behind. The sacral hiatus is then elongated considerably.

Fig. 279.—The base of the sacrum.

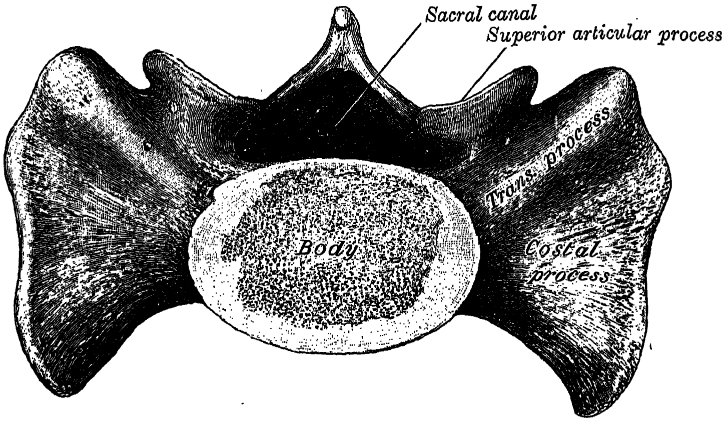
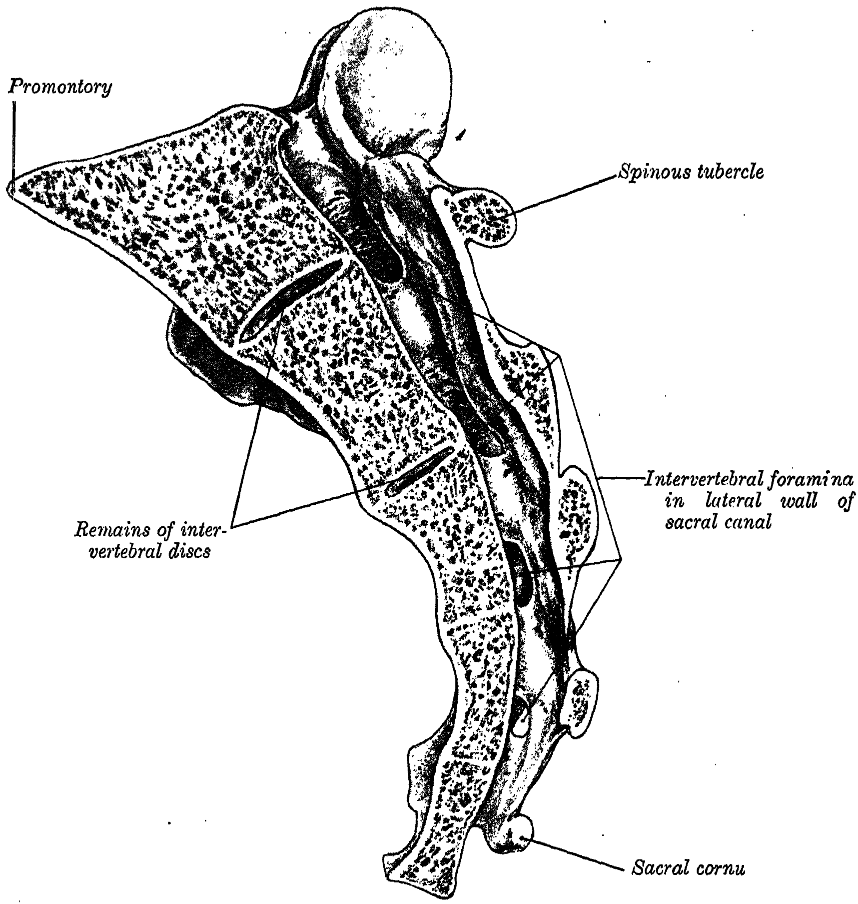


Fig. 280.—A median sagittal section through the sacrum.



The *auricular surface* is covered with hyaline cartilage in the recent state and is formed entirely by the costal elements. The rough area behind it shows two well-marked depressions and gives attachment to the strong interosseous sacro-iliac ligaments. Below the auricular surface the lateral aspect of the sacrum gives attachment to the gluteus maximus,

the sacrotuberous and sacrospinous ligaments and the coccygeus muscle, the structures being enumerated from behind forwards.

The *sacral canal* contains the cauda equina (including the filum terminale) and the spinal meninges. Opposite the middle of the sacrum the subarachnoid and subdural spaces become closed, and the lower sacral nerve roots and the filum terminale pierce the arachnoid and dura mater at that level. The filum terminale emerges below at the sacral hiatus and passes downwards across the posterior surface of the fifth sacral vertebra and the sacrococcygeal joint to reach the coccyx. The fifth sacral nerve also emerges through the sacral hiatus close to the medial side of the sacral cornu and grooves the lateral part of the body of the fifth sacral vertebra.

Differences in the sacrum of the male and female.—In the female the sacrum is shorter and wider than in the male, reflecting the necessity for a wider and a shallower pelvic cavity. The upper part of the bone is flattened, and the lower part curved abruptly forwards, whereas in the male the curvature is more evenly distributed over the whole length of the bone. It should be remembered, however, that the curvature of the bone may vary considerably in different specimens of the same sex. In the female the pelvic surface of the bone faces downwards more than in the male; this increases the size of the pelvic cavity and renders the sacrovertebral angle more prominent. In the female the auricular surface for articulation with the ilium is shorter than that in the male, extending along the sides of the first and second sacral vertebræ only; in the male it is continued down to the middle or lower limit of the third vertebra. No difficulty will be experienced in distinguishing a typical male or a typical female sacrum, but, as the sexual characters are not always pronounced, there are many cases in which it is by no means easy to determine the sex. When any difficulty is experienced in determining the sex of a sacrum, greatest stress should always be laid on the relationship between the length and the breadth of the bone.

Structure.—The sacrum consists of spongy substance enveloped by a thin layer of compact bone.

Variations—Either the fifth lumbar vertebra or, more commonly, the first coccygeal vertebra may become incorporated in the sacrum, which then has six vertebræ. The inclusion of the fifth lumbar vertebra is usually incomplete and it may be limited to one or other side. In the most minor degree of the abnormality the transverse process of the fifth lumbar vertebra is unusually large, and articulates with the sacrum at the posterolateral part of the upper surface of its lateral mass. Reduction of the number of the constituents of the sacrum is less common. The transverse process of the first sacral segment may not be joined to the rest of the lateral mass on one or both sides, and a considerable part of the posterior wall of the sacral canal may be wanting, in consequence of the imperfect development of the laminæ and spines.

THE COCCYX [OS COCCYGIS]

General features.—The **coccyx** (figs. 281, 282) is a small bone, triangular in shape, which consists usually of four rudimentary vertebræ fused together, but the number may be increased to five or reduced to three. Not infrequently, the first coccygeal vertebra exists as a separate piece. The bone is directed downwards and forwards from the apex of the sacrum, so that its pelvic surface faces upwards and forwards and its dorsal surface downwards and backwards.

The *base* of the coccyx, formed by the upper surface of the body of the *first coccygeal vertebra*, presents an oval, articular facet for articulation with the apex of the sacrum. Posterolateral to the facet, two processes, named the *coccygeal cornua*, project upwards to articulate with the sacral cornua; they are the homologues of the pedicles and superior articular processes of the movable vertebræ. A rudimentary *transverse process* projects laterally and slightly upwards from each side of the body of the first coccygeal vertebra and may ascend to articulate or fuse with the inferior lateral angle of the sacrum. In that event five pairs of foramina are found in the sacrum.

The *second, third* and *fourth coccygeal vertebræ* diminish successively in size and are usually fused with one another. They are mere nodules of bone, which represent the rudimentary bodies of the vertebræ, although the second may show traces of transverse processes and pedicles.

Particular features.—The lateral parts of the *anterior surface*, including the rudimentary transverse process, give insertion to the levatores ani and the coccygei. The anterior sacrococcygeal ligament is attached to the front of the body of the first, and may extend downwards to reach the second, coccygeal vertebra (fig. 540). The *cornua* give attachment to the intercornual ligaments. The interval between the body of the fifth sacral vertebra and the articulating sacral and coccygeal cornua on each side represents the intervertebral foramen between the fifth sacral and the first coccygeal vertebra, and transmits the fifth sacral nerve. The posterior primary ramus of that nerve descends behind the rudimentary *transverse process*, but its anterior primary ramus passes forwards through a foramen placed between the transverse process and the sacrum and bounded laterally by the lateral sacrococcygeal ligament, which connects the process to the inferior lateral angle of the sacrum. The *posterior aspect* of the coccyx gives origin, on each side, to the gluteus maximus muscle and, at its tip, to the sphincter ani externus. The median area gives attachment to the deep and superficial posterior sacrococcygeal ligaments. The latter extends downwards from the margins of the sacral hiatus and may close the lower end of the sacral canal. The filum terminale, which is situated between the two ligaments, blends with them on the posterior surface of the first coccygeal vertebra.

FIG. 281.—The coccyx. Anterior aspect.

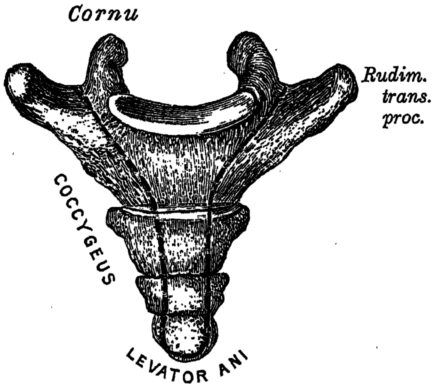
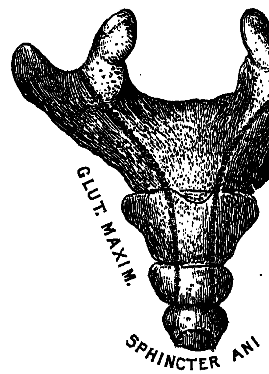


FIG. 282.—The coccyx. Posterior aspect.



The ossification of the vertebral column.—Each typical vertebra is ossified from three primary centres (fig. 283), two for the vertebral arch, and one for the body.* Ossification of the vertebral arches begins in the upper cervical vertebræ about the seventh or eighth week of intrauterine life, and gradually extends down the column. The centres first appear in the situations where the transverse processes afterwards project, and spread backwards to the laminæ, forwards into the pedicles and laterally into the transverse processes. Ossification of the bodies begins in the lower thoracic vertebræ about the eighth week of intrauterine life, and subsequently extends upwards and downwards along the column. The centre for the body constitutes the *centrum*, which does not correspond to the whole of the body of the adult vertebra, for the posterolateral portions of the body are ossified from the centres for the vertebral arch. During the first few years of life the centrum is connected to each half of the vertebral arch by a primary cartilaginous joint, termed the *neurocentral joint*. In the thoracic region the costal facets on the bodies lie behind the neurocentral joints. At birth a vertebra consists of three pieces, viz., the centrum and the halves of the vertebral arch. During the first year the halves of the arch unite behind, union taking place first in the lumbar region and then extending upwards through the thoracic and cervical regions. In the upper cervical vertebræ the centra unite with the arches about the third year, but in the lower lumbar vertebræ union is not completed until the sixth year. Until puberty the upper and under surfaces of the bodies and the ends of the transverse processes and spines are cartilaginous, but about the sixteenth year five secondary centres appear, one for the tip of each transverse process, one for the end of the spine, and two annular epiphyseal discs for the circumferential parts of the upper and lower surfaces of the body (figs. 284, 285). The costal articular facets arise as extensions of the annular epiphyseal discs (Dixon).† These secondary centres fuse with the rest of the bone about the age of twenty-five years. In the bifid spines of the cervical vertebræ there are two secondary centres.

Exceptions to this mode of ossification occur in the first, second, and seventh cervical vertebræ, and in the lumbar vertebræ.

* The body is occasionally ossified from two lateral centres which sometimes fail to unite. The suppression of one of these centres leads to the formation of a wedge-shaped vertebra, and is a well-recognised cause of lateral curvature of the vertebral column. The condition is frequently multiple.

† A. Francis Dixon, *Journal of Anatomy*, vol. lv., October 1920.

The **atlas**, or first cervical vertebra, is usually ossified from three centres (fig. 286). One appears in each lateral mass about the seventh week of intrauterine life, and gradually extends into the posterior arch, where the two unite between the third and fourth years, either directly or through the medium of a separate centre. At birth, the anterior arch consists of fibrocartilage; in this a separate centre appears about the end of the first year, and unites with the lateral masses between the sixth and eighth years—the lines of union extending across the anterior portions of the superior articular facets. Occasionally the anterior arch is formed by the forward extension and ultimate union of the centres for the lateral masses; sometimes it is ossified from two laterally placed centres.

The **axis**, or second cervical vertebra, is ossified from five primary and two secondary centres (fig. 287). The vertebral arch is ossified from two primary centres, and the centrum from one, as in a typical vertebra; the centres for the arch appear about the seventh or eighth week of intrauterine life, the centre for the centrum about the fourth or fifth month. The odontoid process (dens) represents the centrum of the atlas, and is ossified almost entirely from two laterally-placed centres; these appear about the sixth month of intrauterine life, and join before birth to form a conical mass, deeply cleft above. A wedge-shaped piece of cartilage fills the cleft and forms the summit of the process: in this cartilage a centre appears about the second year and unites with the main mass of the process about the twelfth year. It is regarded as representing the proatlas.* The base of the process is separated from the body of the axis by a cartilaginous disc, the circumference of which ossifies, but the centre remains cartilaginous until advanced age; in this cartilaginous disc rudiments of the lower epiphyseal lamella of the atlas and the upper epiphyseal lamella of the axis may sometimes be found. In addition to these centres there is one for a thin epiphyseal plate on the under surface of the body of the bone; it appears about the time of puberty.

The seventh cervical vertebra.—The costal processes of this vertebra are usually ossified from separate centres, which appear about the sixth month of intrauterine life, and join the body and transverse processes between the fifth and sixth years. As already stated (p. 213), the costal processes may persist as separate pieces, and grow laterally and forwards, to constitute cervical ribs.

Separate ossific centres have also been found in the costal processes of the fourth, fifth, and sixth cervical vertebræ.

FIG. 283.—The ossification of a typical vertebra.

By 3 primary centres

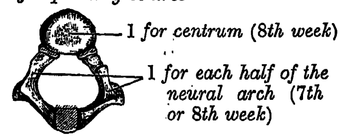


FIG. 284.

By 3 secondary centres

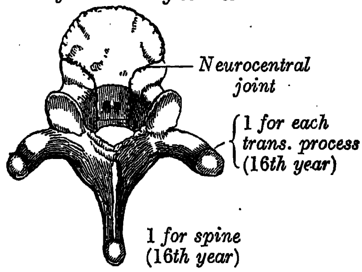
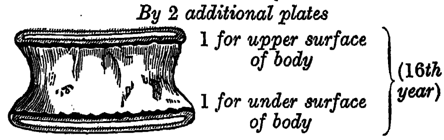


FIG. 285.

By 2 additional plates



Exceptional cases

FIG. 286.—The ossification of the atlas.

By 3 centres

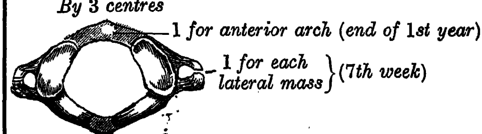


FIG. 287.—The ossification of the axis.

By 7 centres

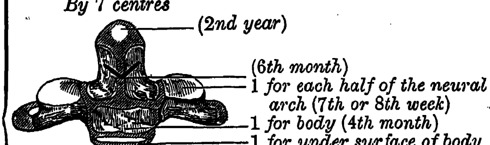
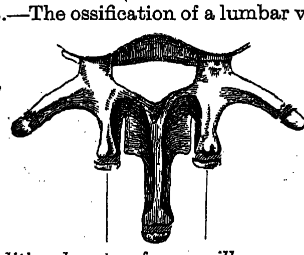


FIG. 288.—The ossification of a lumbar vertebra.



2 additional centres for mamillary processes

* *See* "The Evolution of the Vertebral Column." Edited by J. F. Gaskell and H. L. H. H. Green. Camb. Univ. Press, 1933.

The **lumbar vertebræ** (fig. 288) have each two additional centres, one for each mamillary process.

The **sacrum** (figs. 289 to 292).—Each sacral vertebra is ossified from three primary centres, one for the body and two for the vertebral arch. Two epiphyseal plates are ossified for each body, one for the upper and the other for the lower surface.

FIG. 289.—The ossification of the sacrum and coccyx.

At birth

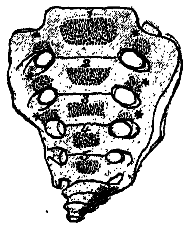


FIG. 290.

At 4½ years

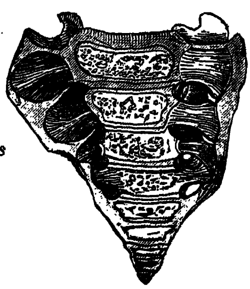


FIG. 291.

The two epiphyseal plates for each lateral surface are marked by asterisks.

At 25th year

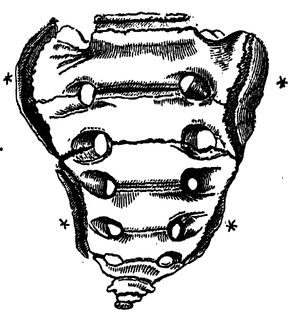
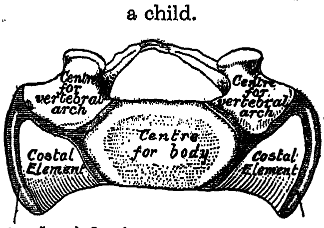


FIG. 292.—The base of the sacrum of a child.



Lateral epiphysis *Lateral epiphysis*

The anterior portions of the lateral masses of the sacrum have six additional (costal) centres, two for each of the first three vertebræ; these appear above and lateral to the anterior sacral foramina (figs. 289, 292).

Two epiphyseal plates are developed on each lateral surface of the sacrum (figs. 291, 292); one for the auricular surface, and another for the thin edge of bone below this surface.

The ends of the spines of the upper three sacral vertebræ are sometimes developed from separate epiphyses, and Fawcett * has pointed out that a number of epiphyses are present in the sacrum at the eighteenth year (fig. 293). These are distributed as follows: One for each of the two mamillary processes of the first sacral vertebra; six on each side, in connexion with the costal processes (two each—an anterior and a posterior—for the first and second, and one each—an anterior—for the third and fourth vertebræ); and eight, four on each side, for the transverse processes, one each for the first, third, fourth and fifth. He is also of opinion (1) that the auricular facets on the lateral surfaces of the sacrum are in the main formed by the development and fusion of the costal epiphyses of the first and second sacral vertebræ, and (2) that the lower part of each lateral surface is formed by the extension and union of the costal epiphyses of the third and fourth, with the epiphyses of the transverse processes of the fourth and fifth sacral vertebræ.

The periods of ossification of the sacrum.—The centres for the bodies of the first, second and third sacral vertebræ appear towards the end of the third month, and those for the bodies of the fourth and fifth vertebræ between the fifth and eighth months of intrauterine life. The centres for the vertebral arches appear about the fifth month, and those for the costal processes of the lateral parts of the bone between the sixth and eighth months of intrauterine life. The first step in the consolidation of the sacrum is the union of these separate parts of the individual vertebræ. The costal element unites with the vertebral arch, before the latter joins the centrum, and this process precedes the union of the laminæ with one another. The fusion of the vertebral arches with the centra is completed at or soon after the eighth year, and traces of the neurocentral joints of the first sacral vertebra can be found after union is complete in the other vertebræ. About the same time or a little later the laminæ fuse with one another, and this process usually begins above and extends in a downward direction, but it is not uncommon to find the laminæ of the fourth sacral vertebræ fused with one another before the process is completed in the first.

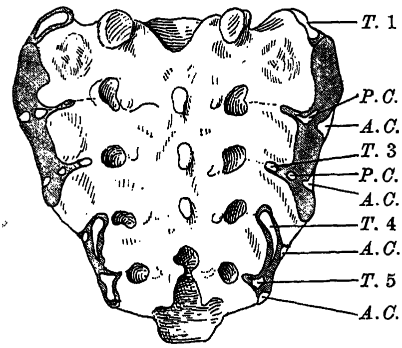
The parts of the individual vertebræ are united before puberty. At that time epiphyseal centres develop (1) for the upper and lower surfaces of the bodies, (2) for the spines,

* E. Fawcett, *Anatomischer Anzeiger*, Bd. xxx., 1907.

and (3) for the extremities of the costal and transverse process elements. At the same time the articular processes and the conjoined costal and transverse process elements begin to fuse with one another, from below upwards, but fusion of the individual vertebræ cannot be completed until the upper and lower epiphyses have united with the bodies, a process which is rarely completed before the twenty-first year. Traces of the intervertebral disc between the first and second sacral vertebræ can be found up to, and often after, middle life.

The **coccyx**.—Each segment of the coccyx is ossified from one primary centre. These appear as follows: in the first segment between the first and fourth years; in the second between the fifth and tenth years; in the third between the tenth and fifteenth years; in the fourth between the fourteenth and twentieth years. A secondary centre appears for each coccygeal cornu, and a pair of epiphyseal plates for each of the rudimentary bodies have been described. As age advances, the segments unite with one another, the union between the first and second being frequently delayed until the age of thirty years. At a late period of life, especially in females, the coccyx often fuses with the sacrum.

FIG. 293.—The epiphyses of the costal and transverse processes of the sacrum at the eighteenth year. (E. Fawcett.)



A.C. 1, 2, 3, 4, Anterior epiphyses for first, second, third and fourth costal processes. *P.C.* 1, 2, Posterior epiphyses for first and second costal processes. *T.* 1, 3, 4, 5, Epiphyses for the first, third, fourth and fifth transverse processes.

THE VERTEBRAL COLUMN AS A WHOLE

The **vertebral column** is situated in the median plane, at the posterior part of the trunk. Its average length in the male is about 70 cm.; of this the cervical part measures about 12 cm., the thoracic 28 cm., the lumbar 18 cm., and the sacrum and coccyx about 12 cm. The average length of the female vertebral column is about 60 cm.

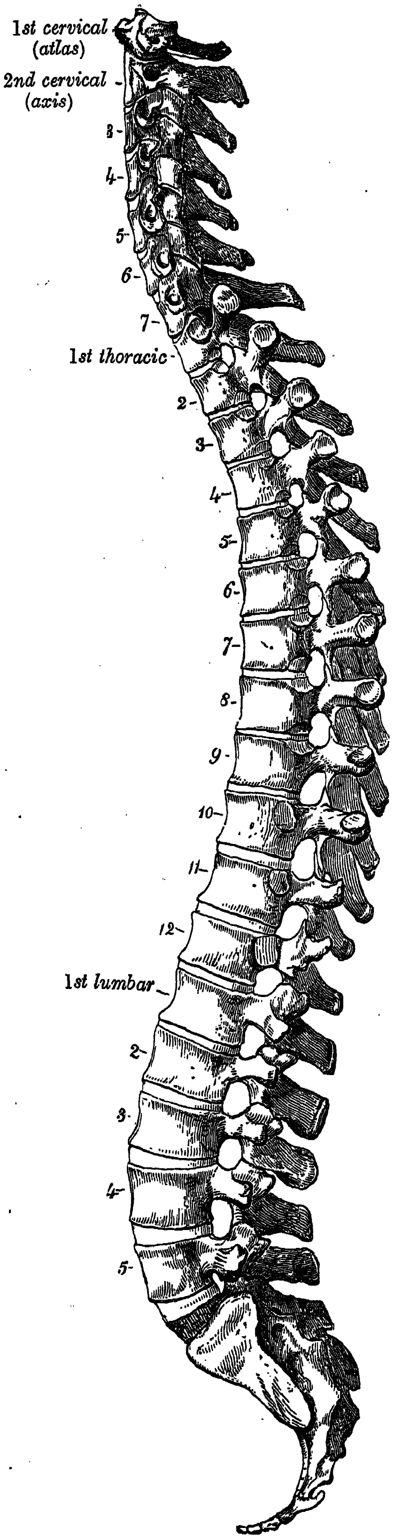
The curves of the vertebral column.—Viewed from the side (fig. 294), the vertebral column presents cervical, thoracic, lumbar, and pelvic curves. The thoracic and pelvic curves are termed primary curves, as they are concave ventrally during fœtal life and retain the same type of curvature after birth. The cervical and lumbar curves are secondary or compensatory; the cervical curve appears late in intra-uterine life and is accentuated when the child is able to hold up its head (at three or four months), and to sit upright (about nine months); the lumbar curve appears at twelve to eighteen months, when the child begins to walk. The *cervical* curve is convex forwards, and is the least marked of the four; it begins at the atlas, and ends at the middle of the second thoracic vertebra. The *thoracic* curve is concave forwards, and reaches from the middle of the second to the middle of the twelfth thoracic vertebra; it is caused by the greater depth of the posterior parts of the vertebral bodies. The *lumbar* curve is convex forwards and is more pronounced in the female than in the male; it reaches from the middle of the last thoracic vertebra to the lumbosacral angle, and the convexity of the lower three segments is greater than that of the upper two; it is caused mainly by the greater depth of the anterior parts of the intervertebral discs, but the shape of the vertebral bodies also helps to produce it. The *pelvic* curve extends from the lumbosacral joint to the apex of the coccyx; its concavity faces downwards and forwards.

In the upper part of the thoracic region of the vertebral column there is sometimes a slight *lateral* curvature, with its convexity directed towards the right side in right-handed persons, and to the opposite side in the left-handed.

The *anterior surface* of the vertebral column.—When viewed from the front, the width of the bodies of the vertebræ is seen to increase from the second cervical to the first thoracic; there is then a slight diminution in the next three vertebræ: below this there is again a gradual and progressive increase in width down to the lumbosacral angle. From this level there is a rapid diminution, to the apex of the coccyx.

The *posterior surface* of the column presents the spines of the vertebræ in the median plane. In the cervical region (with the exception of the second and seventh

FIG. 294.—The vertebral column. Left lateral aspect.



vertebræ) these are short and nearly horizontal, with bifid ends. In the upper part of the thoracic region they are directed obliquely downwards; in the middle part they are long and almost vertical; in the lower part of the thoracic region and in the lumbar region they are nearly horizontal. They are separated by considerable intervals in the cervical and lumbar regions, but are closely approximated in the middle of the thoracic region. Occasionally a spine may deviate from the median plane—a fact to be remembered in practice, as irregularities of this sort are attendant also on fractures or displacements of the vertebral column. At the sides of the spines the *vertebral grooves* lodge the deep muscles of the back. In the cervical and lumbar regions these grooves are shallow and are formed by the laminæ of the vertebræ; in the thoracic region they are deep and wide, and are formed by the laminæ and transverse processes. Lateral to the laminæ are the articular processes, and still more lateral the transverse processes. In the thoracic region the transverse processes lie on a plane considerably behind that of the same processes in the cervical and lumbar regions. In the cervical region the transverse processes are placed in front of the articular processes, lateral to the pedicles, and between the intervertebral foramina. In the thoracic region they are behind the pedicles, intervertebral foramina, and articular processes. In the lumbar region they are in front of the articular processes, but behind the intervertebral foramina. The size of the transverse processes of the atlas has already been emphasised (p. 209), and the breadth from the tip of one transverse process to the tip of the other has been contrasted with the same measurement in the axis. This measurement shows little variation from the second to the sixth cervical vertebra, but in the seventh it shows a substantial increase. In the thoracic region the measurement is greatest in the first and then gradually diminishes, being least in the twelfth, where the transverse process elements are usually reduced to mere vestiges. In the first lumbar vertebra the measurement is greater, in the second it is further increased, while in the third it is greater than it is in any of the other vertebræ. In the fourth and fifth it suffers a slight reduction.

The *lateral surfaces* of the vertebral column are separated from the posterior surface by the articular processes in the

cervical and lumbar regions, and by the transverse processes in the thoracic region. The anterior part of the lateral surface of the column is formed by the sides of the bodies of the vertebræ, marked in the thoracic region by the facets for articulation with the heads of the ribs. The intervertebral foramina are placed behind the bodies and between the pedicles; they are oval in shape, smallest in the cervical and upper part of the thoracic regions, and gradually increasing in size to the last lumbar; they transmit the spinal nerves and vessels.

The *vertebral canal* follows the curves of the column; it is large and triangular in the cervical and lumbar regions, where movement is free, but small and circular in the thoracic region, where motion is more limited.

Applied Anatomy.—Although there is only a very limited amount of movement between any two contiguous vertebræ, there is a considerable range of movement in the vertebral column as a whole. The intervertebral discs act as buffers between the different segments and counteract or neutralize the effect of jars or shocks which may be applied to the column; for example, dropping from a height on to the feet rarely causes concussion of the brain or spinal cord. The security of the column is also increased by the presence of the curves, which enable it to bend without breaking. The vertebræ are so firmly united to one another that violence applied to the column is more likely to produce fracture or dislocation than a tearing of ligaments.

Fractures or fracture dislocations of the vertebral column are the result of (1) forced flexion, e.g. by a violent blow on the back from a large object, and (2) violence transmitted along the long axis of the column, e.g. by falling on to the feet from a height, or by diving on to the head. In the first group the injury commonly occurs at the level of T. 5 or T. 6. In the second group, owing to the normal curvature of the vertebral column, the injury is also a flexion fracture and its site is between T. 9 and L. 2. In either case the upper segment is driven forwards on the lower, and the spinal cord is compressed between the body of the vertebra immediately below, and the arch of the vertebra immediately above the injury. Since the spinal cord does not extend below the level of the upper border of the second lumbar vertebra it follows that partial dislocations, or gunshot wounds, below this level are less serious than those above it.

THE STERNUM

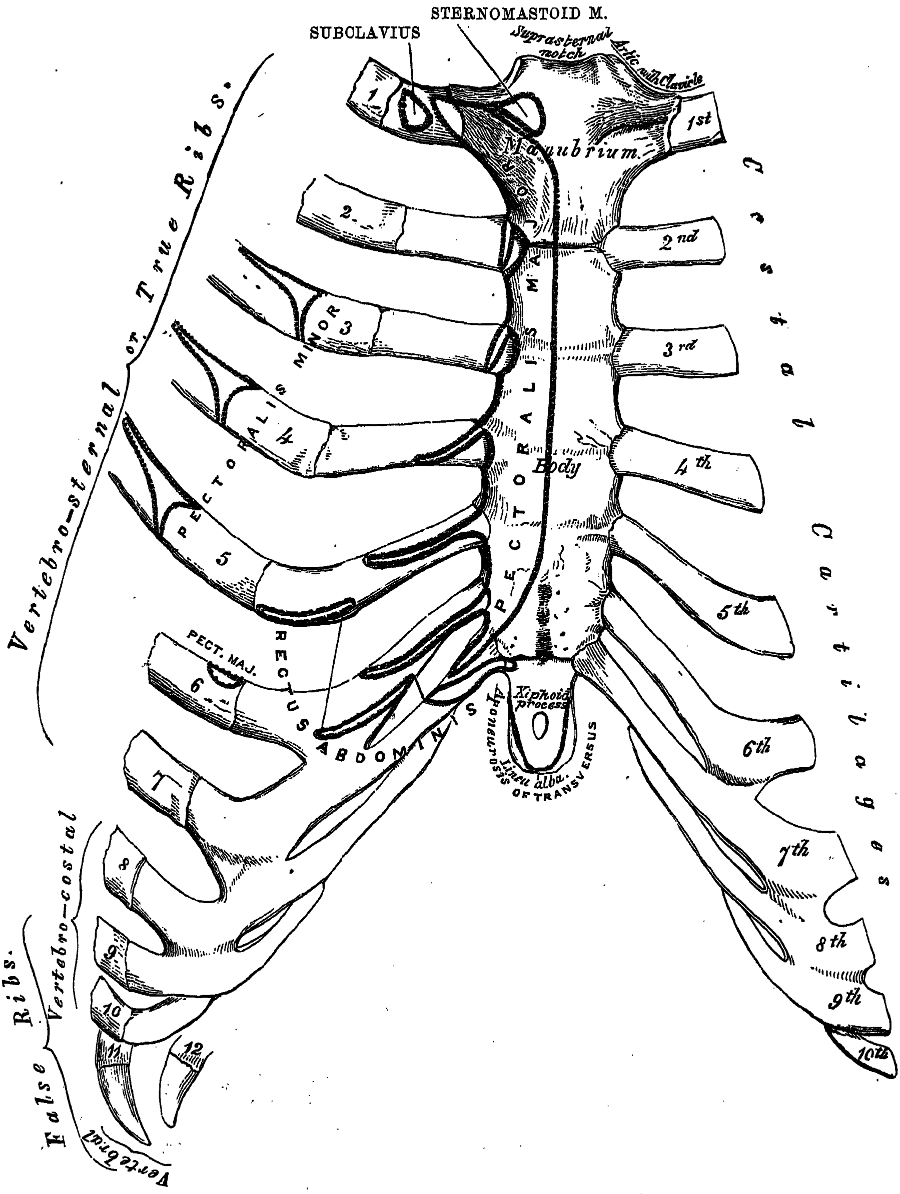
General features.—The **sternum** (figs. 295 to 297) is a long flat bone, forming the median portion of the anterior wall of the thorax. Its average length is 17 cm., and is rather greater in the male than in the female. Its upper end supports the clavicles, and its margins articulate with the cartilages of the first seven pairs of ribs. It consists of three parts, named from above downwards, the *manubrium*, the *body* and the *xiphoid process*; in early life the body consists of four segments. In its natural position the inclination of the bone is oblique from above, downwards and forwards. It is slightly convex in front, and concave behind; it is broad above, narrow at the junction of the manubrium with the body, below which it gradually widens as far as the level of the articulations of the cartilages of the fifth ribs, and then narrows quickly to its lower end.

The **manubrium sterni** is of a somewhat triangular form, broad and thick above, narrow below at its junction with the body. Its *anterior surface* is smooth, convex from side to side and concave from above downwards. Its *posterior surface* is concave and featureless. The *superior border* is thick, and presents at its centre the *suprasternal (jugular) notch*; on each side of this notch there is an oval articular surface, directed upwards, backwards, and laterally, for articulation with the sternal end of the clavicle, and termed the *clavicular notch*. The *inferior border*, oval and rough, is covered in the recent state with a thin layer of cartilage, for articulation with the upper end of the body. The *lateral borders* are each marked above by a depression for the reception of the first costal cartilage, and below by a small articular facet, which, with a similar one on the upper angle of the body, forms a notch for the sternal end of the cartilage of the second rib. Between the depression for the first costal cartilage and the facet for the second, the narrow curved edge slopes from above downwards and medially. The widest part of the sternum is at the level of the first costal cartilages.

The **body** of the sternum is longer, narrower, and thinner than the manubrium, and attains its greatest breadth close to the lower end. Its *anterior surface*, nearly flat, is directed forwards and upwards, and is marked by three ill-defined transverse ridges, which indicate the lines of fusion of four originally separate segments. A

sternal foramen, of varying size and form, is occasionally seen at the junction of the third and fourth pieces of the body (p. 86). The *posterior surface*, slightly concave, is also marked by three transverse lines, less distinct, however, than those on the anterior surface. The *upper end* is oval and articulates with the manubrium at the *sternal angle*, which forms a ridge that can be felt through the skin without difficulty. The *lower end* is narrow, and articulates with the xiphoid process. Each *lateral*

FIG. 295.—The sternum and costal cartilages. Anterior aspect.



border (fig. 297), at its superior angle, has a small notch, which, with a similar one on the manubrium, forms a cavity for the reception of the sternal end of the cartilage of the second rib; below this, four *costal notches* articulate with the sternal ends of the cartilages of the third, fourth, fifth and sixth ribs; the inferior angle has a small facet, which, with a similar one on the xiphoid process, forms a notch for the reception of the cartilage of the seventh rib. These articular depressions are separated by a series of curved edges, which diminish in length from above downwards, and correspond to the anterior ends of the intercostal spaces.

The **xiphoid process** is the smallest piece of the sternum and is thin and elongated. It is cartilaginous in youth, but, at its upper part, more or less ossified in the adult. Above, it articulates with the lower end of the body of the bone, and on the front of each superior angle there is a facet for a part of the cartilage of the seventh rib.

The xiphoid process varies greatly; it may be broad and thin, pointed, bifid, perforated, curved, or deflected to one or other side.

Particular features.—The manubrium lies opposite the third and fourth thoracic vertebræ. Its *anterior surface*, on each side, gives attachment to the sternal origins of the pectoralis major and sternomastoid muscles. Its *posterior surface* gives origin to the sternothyroid muscle, opposite the first costal cartilage; above this level the most medial fibres of the sternohyoid usually arise from the bone (fig. 296). This surface forms the anterior boundary of the superior mediastinum and its lower part is related to the arch of the aorta,

FIG. 296.—The sternum. Posterior aspect.

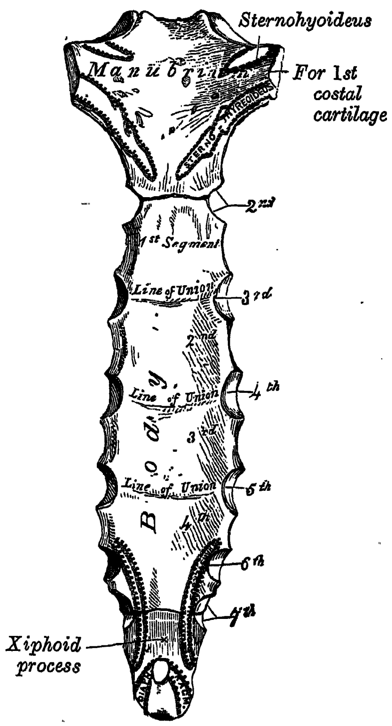
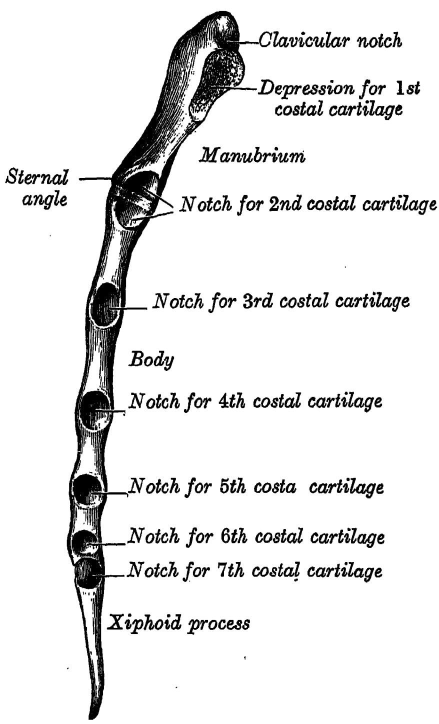


FIG. 297.—The sternum. Lateral aspect.



and its upper part to the left innominate vein and the innominate, left common carotid and left subclavian arteries. Its lateral portions are related to the lungs and pleuræ. The *suprasternal notch* gives attachment to some of the fibres of the interclavicular ligament. On the *lateral border* no joint cavity is interposed between the manubrium and the first costal cartilage, and the union is of the nature of a primary cartilaginous joint.

The **body** lies opposite the fifth to the ninth thoracic vertebræ. Its *anterior surface* gives attachment, on each side, to the articular capsules of the sternocostal joints and to the sternal origin of the pectoralis major muscle. Its *posterior surface* gives origin inferiorly to the sternocostalis (transversus thoracis) muscle, and presents numerous important relationships. On the right side of the median plane it is related to the right pleura and the thin, anterior border of the right lung, which intervene between it and the pericardium. To the left of the median plane the upper two pieces are related to the left pleura and lung, but the lower two are directly related to the pericardium. The *borders* give attachment to the anterior intercostal membranes in the intervals between the costal notches. With the exceptions of the first and the sixth the cartilages of the true ribs articulate with the sternum at the lines of junction of its primitive component segments; this is well seen in many of the lower animals, where the parts of the bone remain ununited longer than in man.

The **xiphoid** process lies in the floor of the epigastric fossa. Its *anterior surface* gives insertion to the most medial fibres of the rectus abdominis and to the aponeuroses of the external and internal oblique muscles. Its *lower end* gives attachment to the linea alba,

and its *borders* to the aponeuroses of the internal oblique and transversus abdominis muscles. Its *posterior aspect* gives origin, on each side, to some of the fibres of the diaphragm, and is related to the anterior surface of the liver.

Structure.—The sternum is composed of highly vascular spongy substance covered by a layer of compact bone, which is thickest on the manubrium between the clavicular notches.

Ossification.—At an early stage of development (p. 86) the sternum consists of two cartilaginous *sternal plates*, one on each side of the median plane. Opposite the first eight pairs of ribs these plates fuse in the median plane about the eighth week to form the cartilaginous sternum, which is ossified from six centres: one for the manubrium, four for the body, and one for the xiphoid process (fig. 298).

FIG. 298.—The ossification of the sternum.

A.—Time of Appearance

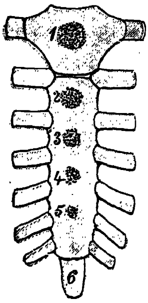
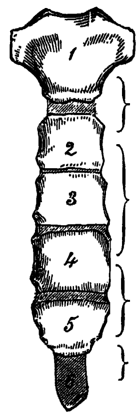


FIG. 299.

B.—Time of union



These centres appear in the intervals between the costal notches in the following order: in the manubrium and first piece of the body, during the sixth month of intrauterine life; in the second and third pieces of the body, during the seventh month of intrauterine life; in the fourth piece, shortly before birth; and in the xiphoid process, in the third year or much later.* Two small episternal centres sometimes appear, one on each side of the suprasternal notch; they are probably vestiges of the episternal bone of the monotremes and lizards. The manubrium may have two, three, or more centres; when two are present, one is generally situated above the other, the upper being the larger. The first segment of the body seldom has more than one centre; but the second, third, and fourth segments are often ossified from two laterally placed centres.

Union between the centres for the body begins about puberty, and proceeds from below upwards (fig. 299); by the age of twenty-five they are all united. The xiphoid process usually fuses with the body about the age of forty years, but may remain ununited in old age. In advanced life the manubrium is occasionally joined to the body by bone, but when this occurs only the superficial part of the intervening cartilage is converted into bone; the central part remains unossified.

THE RIBS [COSTÆ]

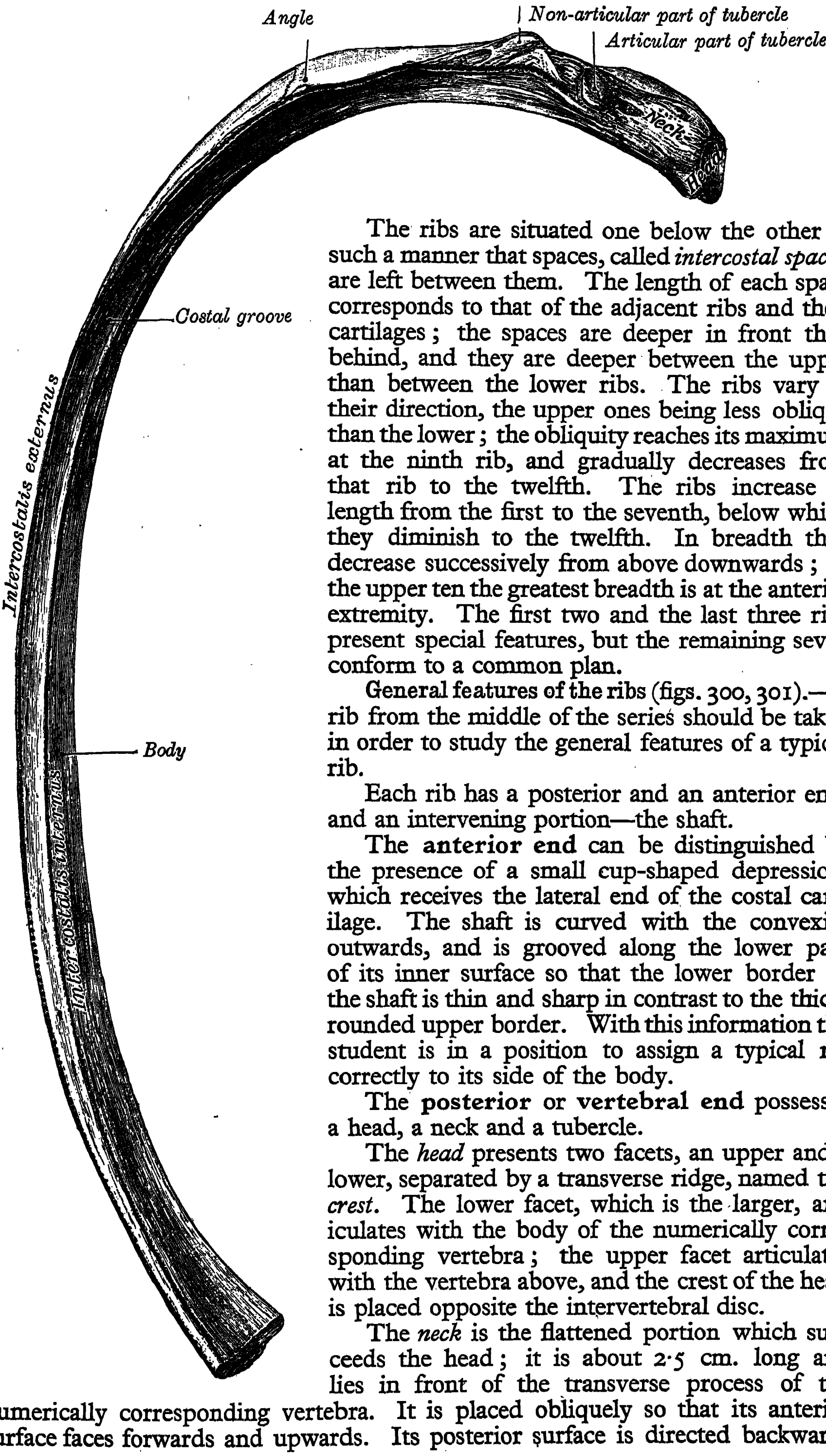
The **ribs** are elastic arches of bone, which are connected behind with the vertebral column, and form a large part of the skeleton of the thorax. They are twelve in number on each side; but this number may be increased by the development of a cervical or a lumbar rib, or may be reduced to eleven. The first seven are connected in front, through the intervention of the costal cartilages, with the sternum (fig. 295); they are called *true* ribs.† The remaining five are *false* ribs; of these

* Paterson (*The Human Sternum*, 1904) found the fourth or lowest centre for the body present only in 26·9 per cent. of cases.

† Sometimes the eighth rib cartilage articulates with the sternum; this condition occurs more frequently on the right side than on the left.

the cartilages of the eighth, ninth and tenth are joined each to the cartilage of the rib immediately above; the eleventh and twelfth are free at their anterior ends and are termed *floating ribs*.

FIG. 300.—A typical rib of the left side. Inferior aspect.



The ribs are situated one below the other in such a manner that spaces, called *intercostal spaces*, are left between them. The length of each space corresponds to that of the adjacent ribs and their cartilages; the spaces are deeper in front than behind, and they are deeper between the upper than between the lower ribs. The ribs vary in their direction, the upper ones being less oblique than the lower; the obliquity reaches its maximum at the ninth rib, and gradually decreases from that rib to the twelfth. The ribs increase in length from the first to the seventh, below which they diminish to the twelfth. In breadth they decrease successively from above downwards; in the upper ten the greatest breadth is at the anterior extremity. The first two and the last three ribs present special features, but the remaining seven conform to a common plan.

General features of the ribs (figs. 300, 301).—A rib from the middle of the series should be taken in order to study the general features of a typical rib.

Each rib has a posterior and an anterior end, and an intervening portion—the shaft.

The **anterior end** can be distinguished by the presence of a small cup-shaped depression, which receives the lateral end of the costal cartilage. The shaft is curved with the convexity outwards, and is grooved along the lower part of its inner surface so that the lower border of the shaft is thin and sharp in contrast to the thick, rounded upper border. With this information the student is in a position to assign a typical rib correctly to its side of the body.

The **posterior or vertebral end** possesses a head, a neck and a tubercle.

The *head* presents two facets, an upper and a lower, separated by a transverse ridge, named the *crest*. The lower facet, which is the larger, articulates with the body of the numerically corresponding vertebra; the upper facet articulates with the vertebra above, and the crest of the head is placed opposite the intervertebral disc.

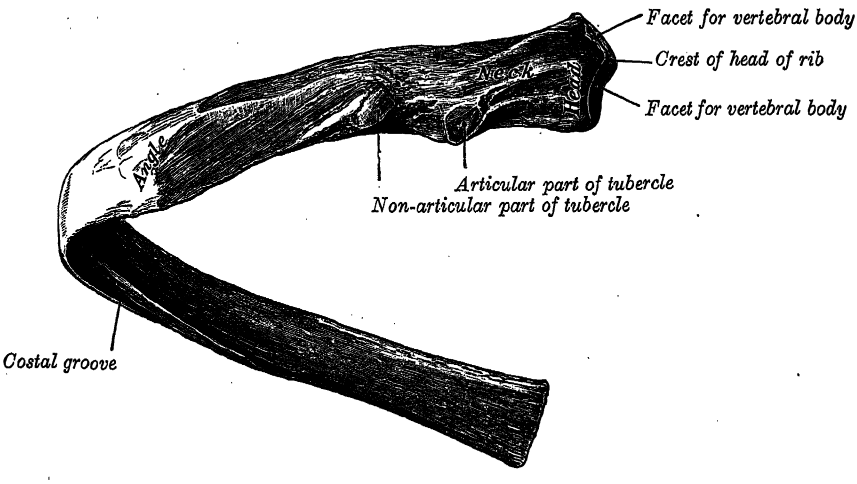
The *neck* is the flattened portion which succeeds the head; it is about 2·5 cm. long and lies in front of the transverse process of the numerically corresponding vertebra. It is placed obliquely so that its anterior surface faces forwards and upwards. Its posterior surface is directed backwards

and downwards, and is roughened and pierced by numerous foramina. Its upper border is sharp and forms the *crest of the neck of the rib*: its lower border is rounded.

The *tubercle* is placed on the outer surface of the posterior part of the rib, at the junction of the neck with the shaft; it is more prominent in the upper than in the lower ribs and is divided into a medial articular and a lateral non-articular portion. The *articular portion* bears a small, oval facet for articulation with the transverse process of the numerically corresponding vertebra; the non-articular portion is rough for ligamentous attachments.

The **shaft** is thin and flattened, with an external and an internal surface, a superior and an inferior border. It is not only curved but is also bent, and the *angle* is situated 5-6 cm. from the tubercle. In addition, the shaft is slightly twisted in its long axis, and this may be demonstrated if the rib is placed with its lower border in contact with a horizontal surface. The part behind the angle inclines medially and upwards, and its outer surface faces downwards and backwards; in front of

FIG. 301.—A typical rib of the left side. Posterior aspect.

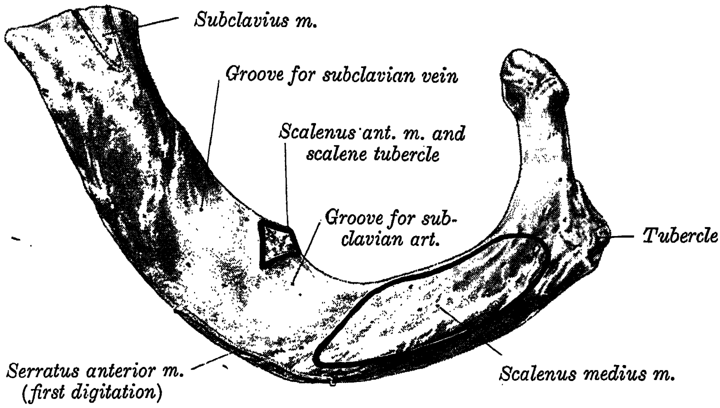


the angle the outer surface faces slightly upwards. The *external surface* is convex and smooth. A short distance from the tubercle it is crossed by a rough line, directed downwards and laterally, which marks the position of the angle. The *internal surface* is smooth and is marked along its lower border by a groove, termed the *costal groove*, which is bounded below by the inferior border of the shaft. The upper border of the groove is continuous behind with the lower border of the neck, but anteriorly it terminates at the junction of the middle and anterior thirds of the shaft; in front of this point, the groove is absent.

The **first rib** (fig. 302) is the most curved and usually the shortest of the ribs; it is broad and flat, its surfaces facing upwards and downwards, and its borders inwards and outwards. It is placed very obliquely in the body—sloping downwards and forwards from its vertebral to its sternal end. The *head* is small and rounded, and bears a single, nearly circular, articular facet, which articulates with the upper part of the side of the body of the first thoracic vertebra. The *neck* is rounded, and is directed upwards, backwards and laterally. The *tubercle*, thick and prominent, is directed upwards and backwards; it bears an oval facet on its medial part for articulation with the transverse process of the first thoracic vertebra. At the tubercle the rib is bent, so that the head of the bone is directed slightly downwards; the angle and the tubercle therefore coincide. The *upper surface* of the shaft is crossed obliquely by two shallow grooves, separated from each other by a slight ridge, which ends at the inner border of the rib in a small projection, termed the *scalene tubercle*. The *under surface* is smooth and has no costal groove. The *outer border* is convex, thick behind, but thin in front. The *inner border* is concave and thin, and marked near its centre by the scalene tubercle. The *anterior end* is larger and thicker than that of any of the other ribs.

The **second rib** (fig. 303) is about twice the length of the first, but has a similar curvature. The non-articular portion of the *tubercle* is often small. The *angle* is slight, and situated close to the tubercle. The *shaft* is not twisted, so that both ends of it touch any plane surface upon which the rib may be laid; but at the tubercle there is an upward convexity, similar to, but smaller than, that found in the

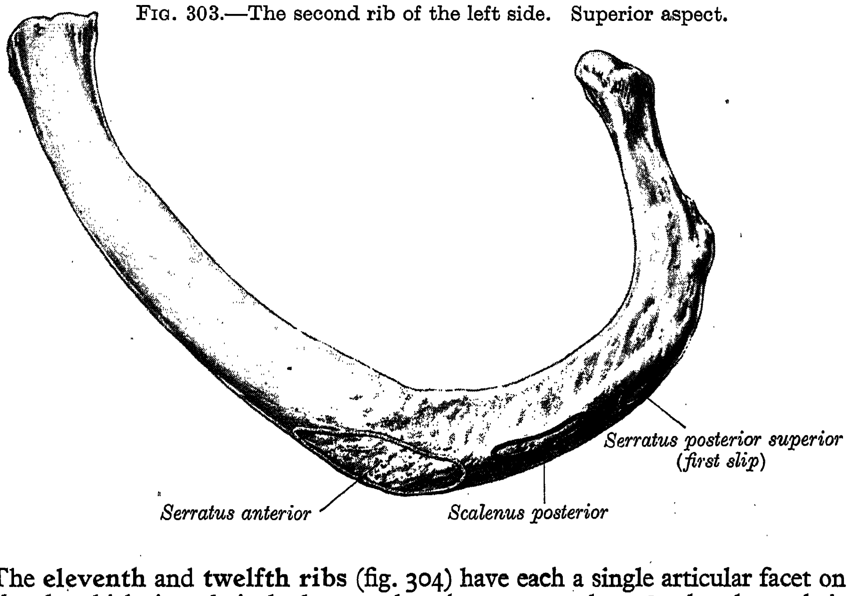
FIG. 302.—The first rib of the left side. Superior aspect.



first rib. The *external surface* of the shaft is convex, and looks upwards and a little outwards; near its middle it is marked by a rough, muscular impression. The *internal surface*, smooth and concave, is directed downwards and a little inwards; on its posterior part there is a short costal groove.

The **tenth rib** has a single articular facet on its head.

FIG. 303.—The second rib of the left side. Superior aspect.

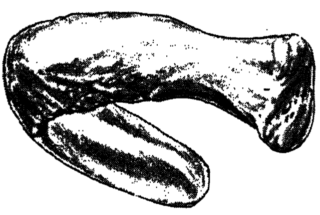


The **eleventh** and **twelfth ribs** (fig. 304) have each a single articular facet on the head, which is relatively large; they have no necks or tubercles; their anterior ends are pointed and tipped with cartilage. The eleventh has a slight angle and a shallow costal groove. The twelfth has neither; it is much shorter than the eleventh, and its vertebral end is directed slightly upwards. The inner surfaces of both ribs look upwards as well as inwards, the upward inclination being more marked in the twelfth. Sometimes the twelfth rib is shorter than the first.

Particular features.—The head *of a typical rib* gives attachment along its anterior border to the radiate ligament, and its crest to the intra-articular ligament. The anterior surface

of the head is related to the costal pleura, and, in the lower ribs, to the sympathetic trunk. The *anterior surface* of the neck is divided into an upper and a lower area by a faint ridge, which affords attachment to the posterior intercostal membrane and is continuous with the inner of the two lips on the superior border of the shaft. The upper area, of varying size and more or less triangular in shape, is separated from the posterior intercostal membrane by some fatty tissue; the lower area is smooth and covered with the costal pleura. The *posterior surface* of the neck gives attachment to the inferior costotransverse ligament (ligamentum colli costæ) and is pierced by numerous vascular foramina. The *crest of the neck* is rough for the attachment of the superior costotransverse (anterior costotransverse) ligament, and it can be traced laterally into the outer lip of the superior border of the shaft. The *inferior border* of the neck is rounded and can be traced laterally into the upper border of the costal groove; it gives attachment to the posterior intercostal membrane. The *articular part of the tubercle* conforms to the shape of the articular facet on the transverse process of the corresponding vertebra. In the upper six ribs it is convex and faces backwards and medially; in the succeeding three or four ribs it is flattened and faces downwards, backwards and slightly medially. The *non-articular part of the tubercle* gives attachment to the lateral costotransverse ligament (ligament of the tubercle of the rib).

FIG. 304.—The twelfth rib of the left side. Viewed from behind.



The ridge which marks the *angle* on the *external surface* of the shaft of a typical rib gives attachment to the upward continuation of the lumbar fascia and the most lateral fibres of the iliocostocervicalis (iliocostalis) muscle. From the second to the tenth ribs the distance between the angle and the tubercle becomes progressively greater. Medial to the angle, the external surface gives attachment to the corresponding levator costæ and is covered by the sacrospinalis muscle. Near the sternal end of this surface an indistinct, oblique line (which marks the anterior angle) separates the origins of the external oblique and the serratus anterior (or latissimus dorsi, in the cases of the ninth and tenth ribs). The *costal groove* on the *internal surface* gives attachment to the internal intercostal muscle, which intervenes between the bone and the intercostal vessels and nerve. At the vertebral end of the bone the groove faces downwards, as its borders lie on the same plane. Near the angle the shaft broadens and the groove passes on to the internal surface. Numerous small nutrient vessels pierce the floor of the groove and traverse the shaft obliquely from before backwards. The upper edge of the groove gives attachment to the intercostalis intimus, which rarely extends on to the anterior fourth of the rib. Posteriorly this edge is continuous with the lower border of the neck. The sharp lower border of the rib gives origin to the external intercostal muscle. Its upper border is marked, posteriorly, by an inner and an outer lip: the inner lip gives attachment to both the intercostalis internus and intimus; the outer lip gives attachment only to the intercostalis externus.

The **first rib** (fig. 302) presents important particular features. The *scalene tubercle* and the adjoining part of the *upper surface* give insertion to the scalenus anterior muscle. The groove in front of the tubercle lodges the subclavian vein, and the irregularly roughened area which intervenes between it and the first costal cartilage gives attachment to the costoclavicular ligament and, more anteriorly, to the subclavius muscle. The groove behind the tubercle is occupied by the subclavian artery and, as a rule, the lower trunk of the brachial plexus.* Behind this groove a rough area which extends as far as the tubercle gives insertion to the scalenus medius. The obliquity of the first rib is responsible for the obliquity of the thoracic inlet and accounts for the appearance of the apex of the lung in the root of the neck.

The *outer border* of the first rib is thin anteriorly but is thicker behind, where it is covered by the scalenus posterior as it descends to the second rib for its insertion. It gives origin to the upper part of the first digitation of the serratus anterior, behind and opposite to the groove for the subclavian artery. The *inner border* gives attachment to the strong fascia which covers the cervical dome of the pleura.

The **second rib** (fig. 303) bears a rough *tubercle for the serratus anterior muscle* on its external surface just behind its midpoint; this tubercle gives origin to the lower part of the first and the whole of the second digitation. The *costal groove* is very poorly marked on the *internal surface* and is restricted to its posterior part. The second intercostal nerve lies between the second rib and the pleura in most of its course. The inner and outer lips of the upper border are distinct and are widely separated behind. Immediately in front of the poorly marked angle the outer lip is roughened to give insertion to the scalenus posterior.

The **twelfth rib** (fig. 304), although short, gives attachment to numerous muscles and ligaments. The lower part of its *anterior surface*, in its medial half to two-thirds, gives

* The intimate relationship of the artery to the first rib is often denied, but it can be demonstrated in most subjects in the dissecting room.

insertion to the quadratus lumborum muscle and its covering fascia. Lateral and superior to these attachments the surface is related to the costodiaphragmatic recess of the pleura. The *lower border* gives attachment to the middle lamella of the lumbar fascia and, at the lateral border of the quadratus lumborum, to the lateral arcuate ligament (lateral lumbocostal arch). The lower border of the neck gives attachment to the lumbocostal ligament, by which it is connected to the transverse process of the first lumbar vertebra. The *external surface* gives attachment to the lowest levator costæ, the longissimus thoracis, and the iliocostalis, in its medial half; more laterally, it gives insertion to the serratus posterior inferior, and origin to the latissimus dorsi and the external oblique muscle of the abdomen.

It should be observed that the lower limit of the pleural sac crosses the anterior aspect of the twelfth rib, approximately at the point where the rib is crossed by the lateral border of the iliocostalis muscle. The lateral extremity of the rib usually lies below the line of pleural reflection and is therefore not covered with pleura.

Structure.—The ribs consist of highly vascular spongy substance, which is enclosed in a thin layer of compact bone, and contains a large proportion of red marrow.

Ossification.—Each rib, with the exception of the first and the last two, is ossified from four centres; a primary centre for the shaft, and three secondary centres, one for the head and one each for the articular and non-articular parts of the tubercle.* The primary centre appears near the angle, towards the end of the second month of intrauterine life, and is seen first in the sixth and seventh ribs. The secondary centres for the head and tubercle appear between the sixteenth and twentieth years, and unite with the shaft about the twenty-fifth year. The first rib has three centres, viz.: a primary one for the shaft, a secondary centre for the head, and one for the tubercle. The eleventh and twelfth ribs, being destitute of tubercles, have each only two centres.

THE COSTAL CARTILAGES

General features.—The **costal cartilages** (fig. 305) are bars of hyaline cartilage which extend forwards from the anterior ends of the ribs and contribute very materially to the elasticity of the walls of the thorax. The first seven pairs are connected with the sternum; the eighth, ninth, and tenth are articulated each with the lower border of the cartilage immediately above; the lower two are pointed, and end in the muscular wall of the abdomen. The costal cartilages vary in their length, breadth and direction. They increase in length from the first to the seventh, and then gradually decrease to the twelfth. They diminish in breadth from the first to the last, like the intervals between them. They are broad at their attachments to the ribs, and taper towards their medial extremities, with the exception of the first and second which are of the same breadth throughout, and the sixth, seventh, and eighth which are enlarged where their margins are in contact. The first cartilage descends a little, the second is horizontal, the third ascends slightly, while the others are angular, continuing the course of the ribs for a short distance, and then inclining upwards to the sternum or preceding cartilage.

Particular features.—Each costal cartilage has two surfaces, two borders, and two ends. The *anterior surface* is convex, and faces forwards and upwards: that of the first gives attachment to the sternoclavicular articular disc, the costoclavicular ligament and the subclavius muscle; those of the first six or seven at their medial ends, to the pectoralis major muscle. The others are covered by, and give partial attachment to, some of the flat muscles of the anterior abdominal wall. The *posterior surface* is concave, and directed backwards and downwards; that of the first gives attachment to the sternothyroid, those of the second to the sixth inclusive to the sternocostalis (transversus thoracis), and the six lower ones to the transversus abdominis and the diaphragm. The *superior border* is concave, and the *inferior* convex; they afford attachment to the internal intercostal muscles and the anterior intercostal membranes. The inferior borders of the sixth, seventh, eighth, and ninth cartilages present heel-like projections at the points of greatest convexity; a similar heel-like projection occurs on the lower border of the fifth right cartilage in 72 per cent. and on the fifth left cartilage in 50 per cent. (Fawcett). On these projections are oblong facets which articulate respectively with facets on slight projections from the superior borders of the sixth, seventh, eighth, ninth, and tenth cartilages. The *lateral end* of each cartilage is continuous with the osseous tissue of the corresponding rib. The *medial end* of the first is con-

* E. Fawcett states that 'in all probability there is usually no epiphysis on the non-articular part of the tuberosity below the sixth or seventh rib' (*Journal of Anatomy and Physiology*, vol. xlv.).

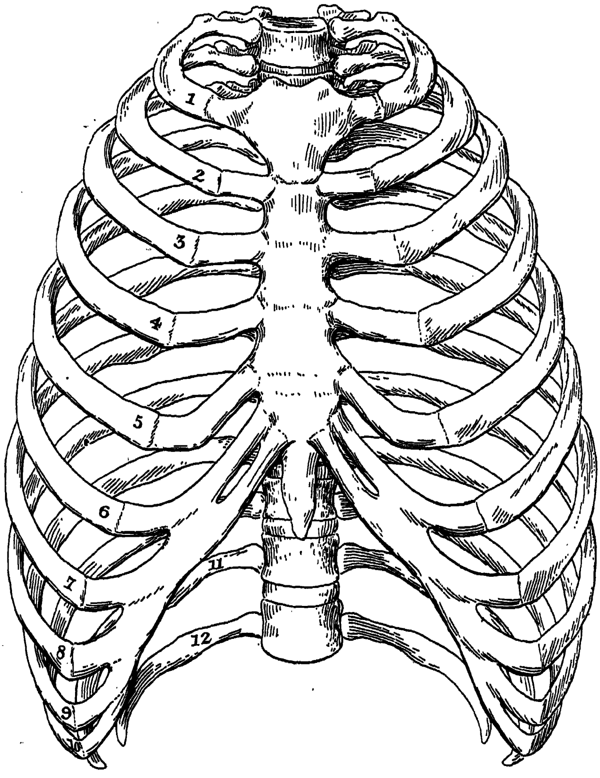
tinuous with the sternum; the medial ends of the six succeeding cartilages are rounded and articulate with the shallow costal notches on the lateral margins of the sternum. The medial ends of the eighth, ninth, and tenth costal cartilages are pointed, and each is connected with the cartilage immediately above. Those of the eleventh and twelfth are pointed and free.

In old age the costal cartilages are prone to undergo superficial ossification.

THE THORAX

The skeleton of the thorax, or chest (fig. 305), is an osseocartilaginous cage which contains and protects the principal organs of respiration and circulation. It is conical in shape, narrow above and broad below, flattened from before backwards, and longer behind than in front. It is reniform on horizontal section on account of the forward projection of the vertebral bodies.

Fig. 305.—The skeleton of the thorax. Anterior aspect.



Boundaries.—*Posteriorly* it is formed by the twelve thoracic vertebræ and the posterior parts of the ribs. At each side of the vertebral column there is a wide and deep groove in consequence of the lateral and backward direction which the ribs follow from their vertebral extremities to their angles. *Anteriorly* it is formed by the sternum, the anterior ends of the ribs and the costal cartilages, and this surface is flattened or slightly convex. *Laterally* it is convex, and is formed by the ribs. The ribs and costal cartilages are separated from each other by the intercostal spaces, eleven in number, which are occupied by the intercostal muscles and membranes.

The *inlet* of the thorax is reniform in shape; its anteroposterior diameter is about 5 cm., its transverse about 10 cm. It slopes downwards and forwards, and is bounded by the first thoracic vertebra behind, the superior border of the manubrium sterni in front, and the first rib on each side. The *outlet* is bounded by the twelfth thoracic vertebra behind, by the twelfth and eleventh ribs at the sides, and in front by the cartilages of the tenth, ninth, eighth, and seventh ribs, which ascend on each side and form an angle, termed the *infrasternal* (*subcostal*)

angle, into the apex of which the xiphoid process projects. The outlet is wider transversely than from before backwards, and slopes obliquely downwards and backwards; it is closed by the diaphragm, which forms the floor of the thorax.

The thorax of the female differs from that of the male as follows: 1. Its capacity is less. 2. The sternum is shorter, and its upper margin is on a level with the lower part of the body of the third thoracic vertebra, whereas in the male it is on a level with the lower part of the body of the second. 3. The upper ribs are more movable and so allow a greater expansion of the upper part of the thorax.

Applied Anatomy.—Fracture of the sternum is by no means common, owing, no doubt, to the elasticity of the ribs and their cartilages, which support it like so many springs.

The ribs are frequently broken, though from their connexions and shape they are able to withstand great force, yielding under pressure and recovering themselves like a spring. The middle ribs are the most liable to fracture. The first, and to a less extent the second, being protected by the clavicle, are rarely fractured; and the eleventh and twelfth on account of their loose and floating condition enjoy a like immunity. The fracture generally occurs from indirect violence from forcible compression of the chest walls, and the bone then gives way at its weakest part, i.e. just in front of the angle. But the ribs may also be broken by direct violence, in which case the bone is driven inwards at the point of impact. Fracture of the ribs is frequently complicated with some injury to the viscera contained within the thorax or upper part of the abdominal cavity; this is most likely to occur in fractures from direct violence.

Cervical ribs derived from the seventh cervical vertebra (page 85) are of not infrequent occurrence, and are important clinically because they may give rise to nervous or vascular symptoms. The cervical rib may be a mere epiphysis articulating only with the transverse process of the vertebra, but more commonly it consists of a definite head, neck and tubercle, with or without a shaft. It extends laterally, or forwards and laterally, into the posterior triangle of the neck, where it may terminate in a free end or may join the first thoracic rib, the first costal cartilage, or the sternum.* It varies much in shape, size, direction, and mobility. If it reaches far enough forwards, its relations are similar to those of the first thoracic rib; part of the brachial plexus and the subclavian artery and vein cross over it, and are apt to suffer compression in so doing. Pressure on the plexus affects the eighth cervical and first thoracic nerves, causing paralysis of the muscles they supply, and neuralgic pains, trophic changes and paræsthesia in the area of skin to which they are distributed: no oculopupillary changes are to be found.

THE SKULL

INTRODUCTORY

The paragraphs which follow are intended primarily for the student who has no previous knowledge of the skull, and may well be omitted by those who are already familiar with its principal features. The detailed description of the skull commences on p. 244.

The skull is the skeleton of the head. It is made up of a large number of bones which, with the exception of the mandible or lower jaw, are so intimately connected to one another that no movement is possible between them. The lines along which the individual bones meet one another are, for the most part, very irregular and are frequently serrated like the edge of a saw (fig. 310). These immovable joints between the bones of the skull are termed *sutures*. They are easily seen in the skulls of young adults, but, as old age approaches, contiguous bones tend to fuse with each other and the suture lines become more or less obliterated.

When the mandible is left out of account the remainder of the skull, strictly speaking, constitutes the cranium, but in this textbook, as well as in many others, the term skull is widely used with the same significance. The upper part of the cranium forms a box to enclose and protect the brain, and is often termed the *calvaria*. The remainder of the skull forms the *facial skeleton*, of which the upper part is immovably fixed to the calvaria and the lower part is the freely movable mandible.

The skull, considered as a whole, is of much greater importance to the student of medicine than the individual bones of which it is made up. Nevertheless, the position of the individual constituents must be determined before the student can be in a position to follow the more detailed description.

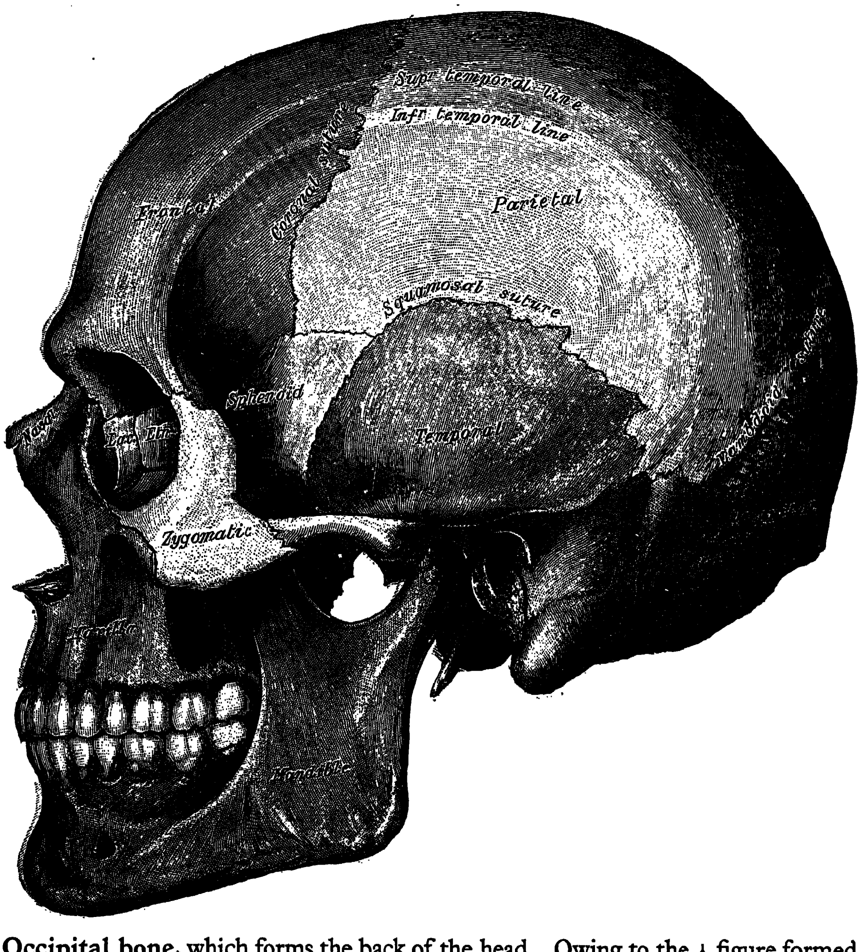
The skull as a whole may be viewed from above (norma verticalis), from below (norma basalis), from behind (norma occipitalis), from in front (norma frontalis)

* W. Thorburn, *The Med. Chronicle*, Manchester, 4th series, xiv. 1907.

and from the side (norma lateralis). The roof of the calvaria, or *skull-cap*, may be removed and the *interior of the skull* may be examined. In the erect attitude the lower margins of the orbital openings and the upper margins of the external auditory meatuses lie on the same horizontal plane, and it is important that the student should bear this in mind when he is examining the various aspects of the skull.

The region of the forehead is formed by the **Frontal bone** (fig. 306), which passes backwards in the vault of the skull as far as the *coronal suture*, where it meets the anterior borders of the right and left **Parietal bones**. These two bones together form the greater part of the top of the head, and they articulate with each other at the serrated *sagittal suture*. Posteriorly they extend backwards to meet the

FIG. 306.—The skull. Lateral aspect. (Norma lateralis.)



Occipital bone, which forms the back of the head. Owing to the λ figure formed by the meeting of the sagittal with the parieto-occipital sutures, the latter are named the *lambdoid suture*. Each parietal bone extends downwards on the side of the vault until it meets the upper limit of the *greater wing* of the **Sphenoid bone** in front, and the *squamous part* of the **Temporal bone** behind. When the skull cap is removed, the section passes through the frontal bone and usually cuts across the lower part of the parietal bone, but it may involve the squamous part of the temporal bone. Posteriorly the section cuts the occipital bone. Consequently, the *skull cap* consists of (1) a large part of the frontal bone, (2) most of the two parietal bones, (3) possibly, small parts of the squamæ of the temporal bones, and (4) a small part of the occipital bone.

When the skull cap is removed, the floor of the calvaria, almost invariably termed the **base of the skull**, is exposed. It shows a natural subdivision into three areas, which are named the anterior, middle and posterior cranial fossæ (fig. 307). The **anterior cranial fossa** forms less than the anterior third of the base and is limited

behind by a sharp edge on each side of the median plane. It is important to observe that the floor of the anterior cranial fossa constitutes the roof of the orbit, on each side, and the roof of the nose, in the median area. On each side of the median plane an *orbital plate* projects backwards from the **Frontal bone** and constitutes most of the roof of the orbit. These two plates are separated by a relatively narrow interval, which is occupied by a perforated strip of bone. This is termed the *cribriform plate* of the **Ethmoid bone**; it forms a large part of the roof of the nose, while the rest of the bone to which it belongs participates in the formation of the side walls of the nose. In the median plane the cribriform plate bears a crestlike elevation, termed the *crista galli*. The most posterior part of the floor of the anterior cranial fossa is formed by the **Sphenoid bone.** In the median area the front of the *body* of the sphenoid meets the cribriform plate of the ethmoid. On each side a narrow *lesser wing* projects laterally from the body of the sphenoid and meets the posterior margin of the orbital plate of the frontal bone. It is the sharp posterior border of the lesser wing of the sphenoid bone which forms the posterior limit of the floor of the anterior cranial fossa on each side of the median plane.

Fig. 307.—The internal surface of the left half of the base of the skull. (Basis cranii interna.)

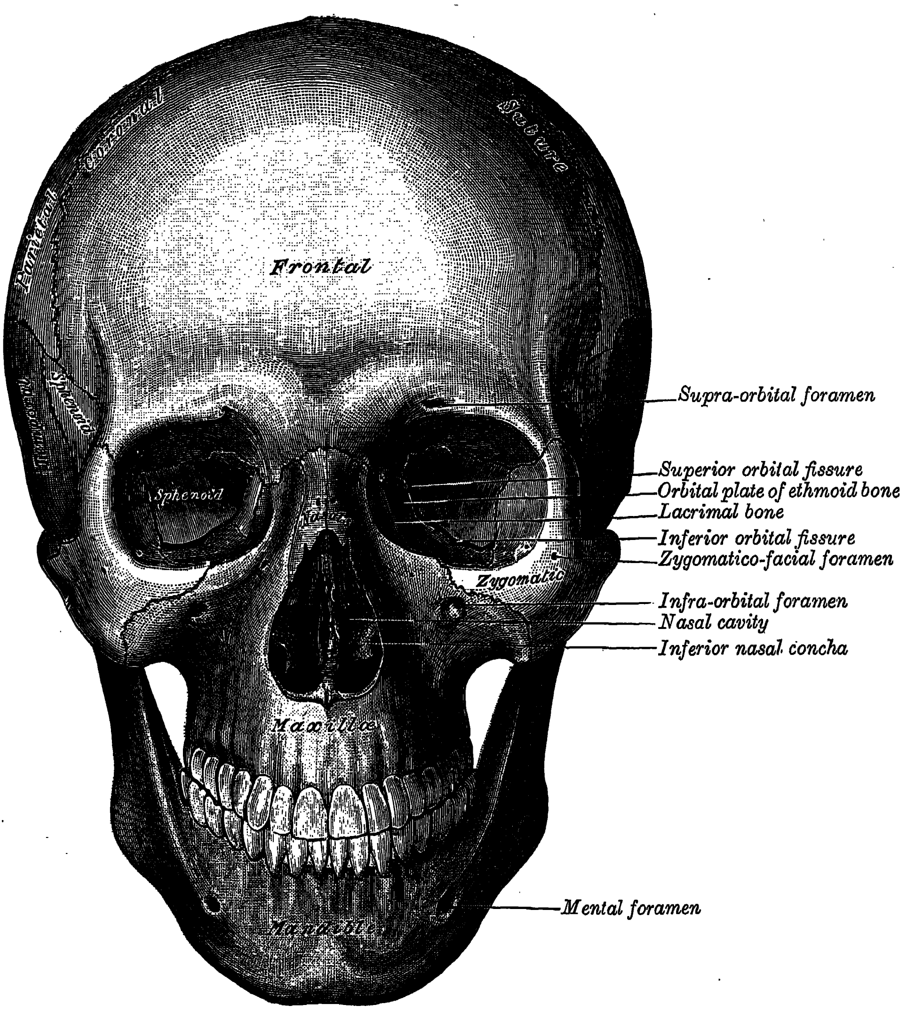
The **middle cranial fossa** (fig. 307), which lies immediately behind the anterior fossa, is of small extent in the median region but is expanded, in a backward and lateral direction, on each side. The narrow median portion of the floor is formed by the *body* of the **Sphenoid,** the upper surface of which is hollowed out to contain the hypophysis cerebri—an important ductless gland. The floor of the lateral part of the fossa is formed by the *greater wing* of the sphenoid in front, and by the *petrous part* of the **Temporal bone** behind. The greater wing extends laterally from the side of the body of the sphenoid and curves upwards in the side of the skull to reach the antero-inferior part of the parietal bone. Behind it the floor of the fossa is formed by the anterior surface of the petrous part of the temporal bone, which is continuous laterally with the squamous part of the same bone.

The **posterior cranial fossa** (fig. 307) is almost circular in outline and occupies roughly two-fifths of the base of the skull. It is formed to a very large extent by the **Occipital bone.** The large opening in its floor, termed the **foramen magnum,** is placed entirely within that bone and allows the brain to become continuous with the spinal cord. The anterior part of the fossa is formed by the *basilar part* of the occipital bone, which is fused in front with the posterior part of the sphenoid bone. On each side the lateral wall of the fossa is formed by the posterior surface of the petrous part of the temporal bone above, and by the *condylar* (lateral) *part* of the occipital bone, below. The *mastoid part*

of the temporal bone, which lies immediately behind the petrous part, helps the *squamous part* of the occipital bone to complete the fossa.

When the skull is viewed from in front (norma frontalis, fig. 308) the **orbits,** which lodge the eyeballs, and the anterior aperture of the **nose,** can easily be identified. The part below the mouth is formed entirely by the *body* of the **Mandible**; the part above the mouth is formed almost entirely by the **Maxillæ,** or upper jaws. These bones form the upper boundary of the mouth, and the lower and lateral boundaries of the anterior nasal aperture. In addition, on each side the

FIG. 308.—The skull. Anterior aspect. (Norma frontalis.)



maxilla forms the medial part of the lower margin of the orbit, which it helps the **Zygomatic bone** to complete, while its frontal process ascends in the medial margin of the orbit to reach the **Frontal bone.** The frontal processes of the two maxillæ are separated from each other by the two **Nasal bones,** which form the upper boundary of the anterior nasal aperture.

When the skull is viewed from the side (norma lateralis, fig. 306) the *ramus* of the **Mandible,** which passes from the posterior end of the body of the bone upwards and slightly backwards to reach the cranium, can be identified without difficulty. The *head* of the mandible, which lies at the upper end of the posterior border of the ramus, is received into the *articular fossa* on the under surface of the squamous part of the temporal bone. The back of the mandibular head is separated

from the ear passage, termed the *external auditory meatus*, by the *tympanic part* of the temporal bone. Above and in front of the meatus the thin *zygomatic process* of the temporal bone passes forwards to meet the zygomatic or cheek bone, and the two form the *zygomatic arch*, which is separated by a wide gap from the rest of the side of the skull. The **Zygomatic bone** is responsible for the prominence of the upper and anterior part of the cheek. It forms the lateral part of the lower margin of the orbital opening, as already stated, and ascends in the lateral margin to meet the **Frontal bone.**

FIG. 309.—The external surface of the left half of the base of the skull. (Norma basalis.) For Key, see fig. 320.

When the mandible is removed (fig. 317) a process of bone can be seen immediately behind the maxilla and above the level of the maxillary teeth. This is the *pterygoid process*, which projects downwards from the **Sphenoid** along the line of union of its greater wing with its body. It consists of a large lateral plate with a smaller, medial plate on its medial side.

The inferior aspect of the cranium (norma basalis, fig. 309) is termed the external aspect of the base of the skull. It should be examined next. Posteriorly the **Occipital bone**, with the foramen magnum, can be located without difficulty. Lateral to the foramen magnum the occipital bone articulates with the *mastoid part* of the **Temporal bone.** Antero-laterally it articulates with the *petrous part*, which extends forwards almost to the root of the *pterygoid process*. In the anterior part of the inferior aspect of the cranium, the **bony palate**, which lies in the roof of the mouth, can be seen within the arch of the teeth of the maxilla. Four bones contribute to its formation, viz., the two **Maxillæ** and the two **Palatine bones.** The anterior three-fourths of the bony palate are formed by the *palatine processes* of the maxillæ, which meet each other in the median plane; the posterior fourth is formed by the *horizontal plates* of the *palatine bones*. The palatine bones are now seen, in part, for the first time; their *perpendicular plates* are still hidden as they ascend, on each side, from the lateral border of the horizontal plate to form the posterior part of the lateral wall of the nose.

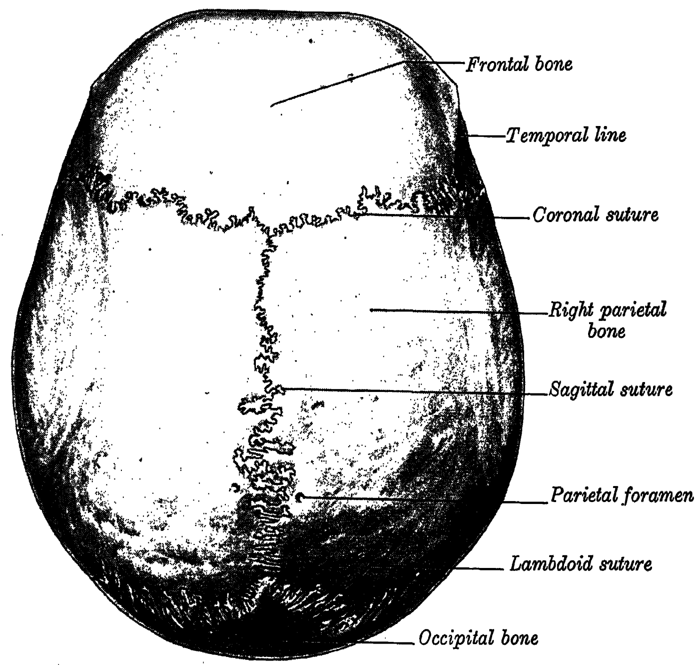
The **Lacrimal bone,** which lies in the anterior part of the medial wall of the orbit, the **Vomer,** which forms a large part of the nasal septum (fig. 328), and the **Inferior Concha,** which lies in the lateral wall of the nose, can be seen only when the orbits and the nose are examined (pp. 247 and 273). With these exceptions all the bones of the skull have now been identified, and the student is in a position to undertake profitably a more detailed study of the skull as a whole.

THE EXTERIOR OF THE SKULL

NORMA VERTICALIS (fig. 310)

The outline of the skull, as seen from above, varies greatly in different specimens. In some the outline is more or less oval: in others it is more nearly circular, but its greatest width is usually nearer to the occipital than to the frontal region. This aspect of the skull is traversed by three sutures. (1) The *coronal suture* is placed between the posterior edge of the frontal bone and the anterior borders of the parietal bones. From the median plane it passes downwards and forwards across the cranial vault. (2) The *sagittal suture* is placed in the median plane between the interlocking upper borders of the two parietal bones. (3) The *lambdoid suture* is placed between the posterior borders of the parietal bones and the superior border of the squamous part of the occipital bone. It runs downwards and forwards across the cranial vault. The meeting-place of the coronal and sagittal sutures is termed

Fig. 310.—The skull, viewed from above.



the *bregma*, and it is the site of a membrane-filled gap in the fœtal skull which is named the *anterior fontanelle* (p. 326). The *lambda* is situated at the junction of the sagittal and lambdoid sutures and is the site of the *posterior fontanelle* (p. 326) in the fœtal skull, which is a similar but smaller gap.

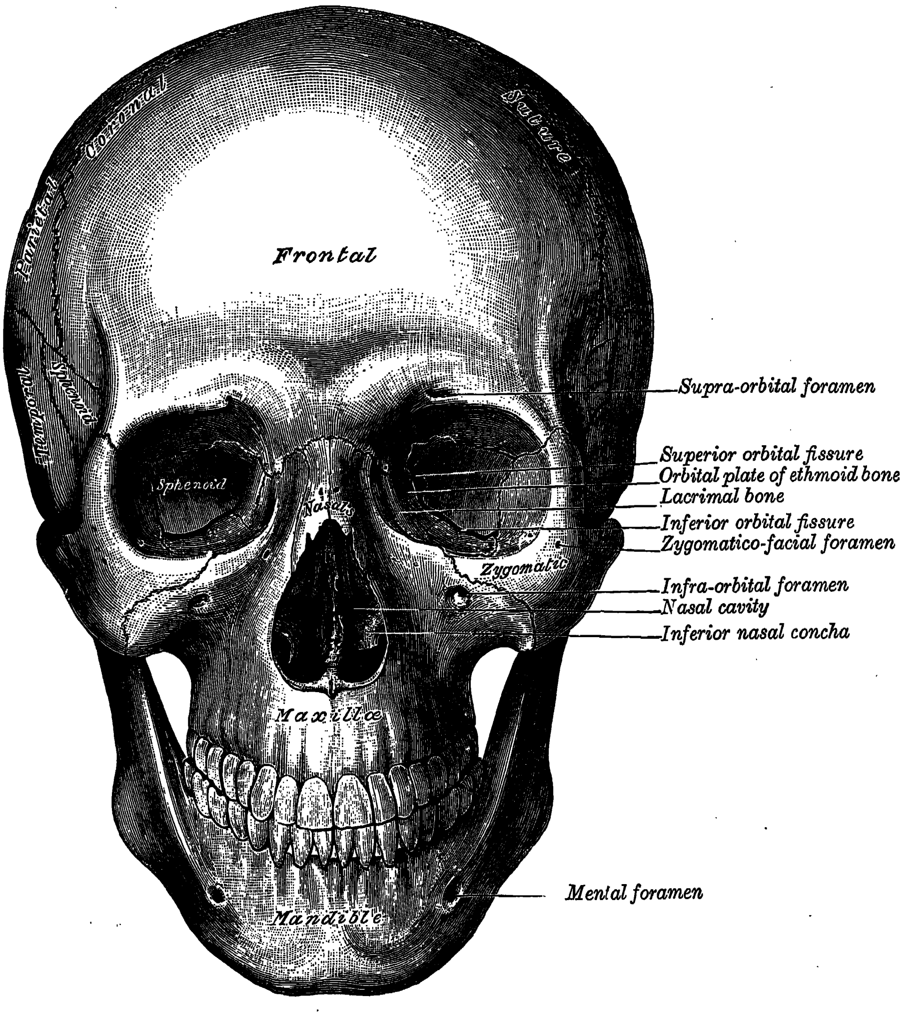
The region of maximum convexity of the parietal bone is termed the *parietal eminence* (tuberosity) and can be identified easily in the living subject. In this situation the norma verticalis passes into the norma lateralis and the norma occipitalis, but there are no sharp lines of demarcation. The *parietal foramen*, which may be absent on one or both sides, pierces the parietal bone near the sagittal suture about 3·5 cm. in front of the lambda. It transmits a small emissary vein from the superior sagittal sinus within the skull, and this vessel constitutes one of the important connexions between the extra- and the intracranial veins. Anteriorly the norma verticalis slopes down into the norma frontalis.

NORMA FRONTALIS (fig. 311)

Viewed from in front the skull exhibits a more or less oval outline, wider above than below. Its upper part is formed by the frontal bone and is smooth and convex. Its lower part is very irregular and is interrupted by the orbits and the anterior bony

aperture of the nose. Immediately above the medial part of each orbit the *superciliary arch* forms a rounded elevation, better marked in the male than in the female skull, and these two arches are connected by a median elevation termed the *glabella*. Below the glabella the skull recedes to the point where the nasal bones meet the frontal, forming the floor of a depression at the root of the nose. The point where the internasal and frontonasal sutures meet is named the *nasion*. Above the superciliary arch on each side there is a slight rounded elevation termed the *frontal*

FIG. 311.—The skull. Anterior aspect. (Norma frontalis.)



eminence. All these are bony landmarks which can be felt without difficulty in the living subject, and the glabella and nasion provide reference points for the surgeon in certain intracranial operations.

The **orbital opening** is more or less quadrangular in shape. Its *supra-orbital margin* is formed entirely by the frontal bone and, at the junction of its sharp lateral two-thirds with its rounded medial third, it presents the supra-orbital notch (or foramen, as the case may be), which transmits the supra-orbital vessels and nerve. The *lateral margin* is formed almost entirely by the frontal process of the zygomatic bone, but it is completed above by the zygomatic process of the frontal bone, and the suture which connects these two bones can be felt in the living subject as a slight depression. The zygomatic bone laterally, and the maxilla medially, share in the formation of the *infra-orbital margin*. Both these margins

are sharp and can be felt easily through the skin. The *medial margin* is not so clear-cut; it is formed above by the frontal bone and below by the lacrimal crest of the frontal process of the maxilla, which is sharp and distinct in its lower half only.

The **anterior bony aperture of the nose** is pear-shaped, wider below than above and bounded by the nasal bones and the maxillæ. The two nasal bones articulate with each other in the median plane and both articulate with the frontal bone above. On each side the nasal bone articulates behind with the frontal process of the maxilla, but its lower border, to which the upper nasal cartilage (fig. 1003) is attached in the fresh specimen, is free and forms the upper boundary of the bony nasal aperture.

The maxillæ take a very large share in the formation of the skeleton of the face, and it is the growth of these bones which is responsible for the elongation of the face that occurs between the ages of 6 and 12. It is only the anterior surface of the maxilla which is visible in the norma frontalis. Medially this surface presents the well-marked *nasal notch*, which forms the lower border and the adjoining part of the lateral border of the anterior bony aperture of the nose. A prominent, sharp projection marks the meeting of the two maxillæ in the lower boundary of the aperture and is termed the *anterior nasal spine*. It can be identified in the lower border of the free part of the nasal septum in the living subject. About 1 cm. below the infra-orbital margin the maxilla is perforated by the *infra-orbital foramen*, which transmits the infra-orbital vessels and nerve; it lies on, or just lateral to, a vertical line passing through the supra-orbital notch. The *alveolar process* of the maxilla, which provides the sockets for the maxillary teeth, can be examined most satisfactorily in the norma basalis (p. 256). The *zygomatic process* of the maxilla is a short but stout projection from the upper and lateral part of the anterior surface of the bone. Its upper surface is oblique and articulates with the zygomatic bone at the zygomaticomaxillary suture. Inferiorly it presents a free lower border, which meets the body of the bone above the first molar tooth, and can be palpated through the skin of the cheek or through the mucous membrane of the vestibule of the mouth. The *frontal* process of the maxilla ascends behind the nasal bone, forming the lower part of the medial margin of the orbital opening, and reaches the frontal bone. It will be examined subsequently, both in the orbit and in the nose.

The *prominence of the cheek* below and lateral to the orbit is produced by the zygomatic bone. It is the convex lateral surface of the bone which can be examined both in the norma frontalis and in the norma lateralis. Its contributions to the margins of the orbital opening and its articulation with the maxilla have already been noted.

The mandible is described on p. 277.

Particular features.—The *glabella* may show the remains of the frontal suture, which in about 9 per cent. of skulls extends upwards to the coronal suture. It indicates that the adult frontal bone is formed by the fusion of right and left halves, which ossify independently of each other. The medial part of the *superciliary arch* gives origin to the corrugator muscle. The nasal part of the frontal bone and the frontal process of the maxilla give origin to the orbital part of the orbicularis oculi muscle. Between these two areas the medial palpebral ligament is attached to the frontal process of the maxilla (fig. 381). The procerus muscle arises from the nasal bone near the median plane. The lower margin of the nasal bone usually presents a small notch, converted into a foramen in the fresh specimen by the lateral cartilage of the nose. It transmits the external nasal nerve. In front of the orbicularis oculi the levator labii superioris alæque nasi (angular head of the quadratus labii superioris) takes origin from the frontal process of the maxilla. More laterally, the levator labii superioris (infra-orbital head of the quadratus labii superioris) arises from the maxilla in the interval between the infra-orbital margin and the foramen of the same name.

The stout root of the canine tooth produces an elevation termed the *canine eminence*, which separates the *canine fossa* on its lateral side from the *incisive fossa* on its medial side. The levator anguli oris (m. caninus) arises from the canine fossa, while the incisive fossa gives origin to the compressor naris muscle (transverse part of the m. nasalis). Below these fossæ the anterior surface of the maxilla gives origin to the depressor septi, the dilator naris (alar part of m. nasalis) and the incisive muscle of the upper lip.

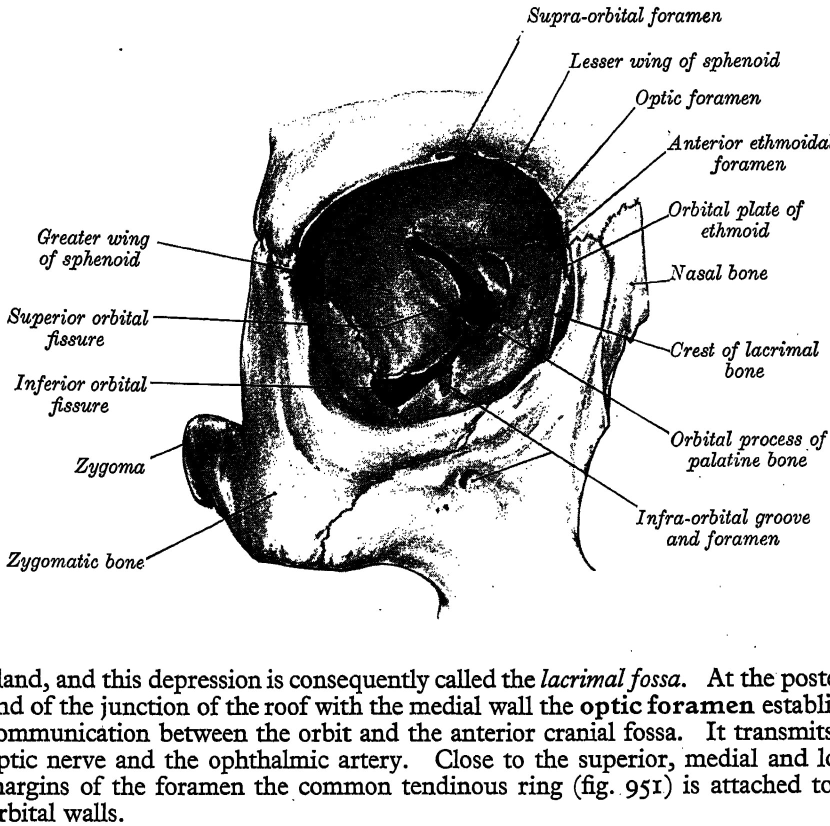
The zygomatic bone is marked opposite the junction of the infra-orbital and lateral margins of the orbit by the small *zygomaticofacial foramen*, which transmits the nerve of the same name and a minute artery. The foramen, which is sometimes duplicated, opens laterally and downwards. Below the foramen the zygomatic bone gives origin to the zygomaticus minor muscle (zygomatic head of the m. quadratus labii superioris), and more laterally to the zygomaticus major muscle (m. zygomaticus).

The Orbit (figs. 312–315)

General features.—The **orbits** are a pair of roomy cavities which contain the eye-balls, their associated muscles, vessels, nerves, etc., and most of the lacrimal apparatus, together with a variable amount of soft fat. The orbital cavity is pyramidal in shape; its base is the orbital opening on the face, and its long axis is directed backwards and medially. Each orbit presents a roof, a floor, medial and lateral walls, a base or orbital opening and an apex.

The **roof** is a thin, gently concave plate of bone which intervenes, throughout most of its extent, between the orbit and the part of the brain in the anterior cranial fossa. In its anteromedial part it is separated into two laminæ by the frontal sinus, which is an air-space in the bone communicating with the nasal cavity. In its anterolateral part it is deeply hollowed out to contain the orbital part of the lacrimal

Fig. 312.—The right orbit, viewed from in front.



gland, and this depression is consequently called the *lacrimal fossa*. At the posterior end of the junction of the roof with the medial wall the **optic foramen** establishes communication between the orbit and the anterior cranial fossa. It transmits the optic nerve and the ophthalmic artery. Close to the superior, medial and lower margins of the foramen the common tendinous ring (fig. 951) is attached to the orbital walls.

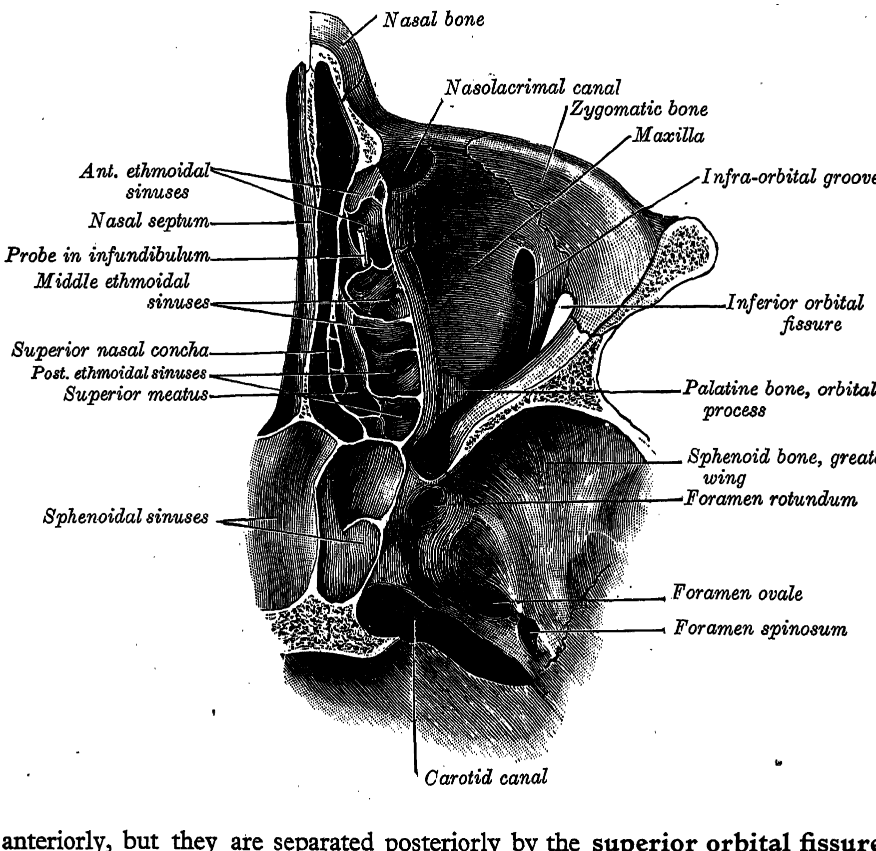
The **medial wall** (fig. 314) is exceedingly thin, except at its most posterior part, and slopes gently downwards and laterally into the floor. Anteriorly, it presents the *lacrimal groove*, which lodges the lacrimal sac. The groove communicates below with the nasal cavity through the *nasolacrimal canal*, which is little more than 1 cm. long and transmits the nasolacrimal duct. The floor of the groove separates the orbital cavity from the nasal cavity, but behind the groove the air-containing ethmoidal sinuses intervene between the two cavities. Posteriorly the medial wall is related to the anterior part of the sphenoidal sinus and forms its lateral wall.

The **floor** of the orbit (fig. 313) is relatively thin and constitutes, in most of its extent, the roof of the maxillary sinus (fig. 314). It is not quite horizontal, but faces upwards and slightly laterally. In front it is directly continuous with the lateral wall, but posteriorly the two walls are separated by the **inferior orbital fissure.** This fissure leads into the orbit from the pterygopalatine fossa posteriorly,

and from the infratemporal fossa anteriorly. The maxillary nerve is the most important structure which it transmits. The lower lip of the fissure is notched by the *infra-orbital groove*, which passes forwards in the floor, sinking into it anteriorly and becoming converted into the *infra-orbital canal*. The anterior opening of the canal forms the infra-orbital foramen. The groove, canal and foramen transmit the infra-orbital nerve, which is the continuation of the maxillary nerve. Through the anterior part of the inferior orbital fissure a vein passes to connect the inferior ophthalmic vein with the veins of the pterygoid plexus in the infratemporal fossa.

The **lateral wall** (fig. 315) is the thickest of the orbital walls, especially behind, where it separates the orbit from the middle cranial fossa. In front it is interposed between the orbit and the temporal fossa. The lateral wall and the roof are continuous

FIG. 313.—A horizontal section through the nasal and orbital cavities. Superior aspect.



anteriorly, but they are separated posteriorly by the **superior orbital fissure.** This important fissure is noticeably widened at its medial end (fig. 312), and its long axis is directed medially, backwards and slightly downwards. It communicates with the middle cranial fossa and transmits the oculomotor, trochlear and abducent nerves and the terminal branches of the ophthalmic nerve, together with the ophthalmic veins. Where the fissure begins to widen its lower border is marked by a bony projection, often sharp in character, which gives attachment to the lateral part of the common tendinous ring for the origin of certain muscles of the eyeball (fig. 951).

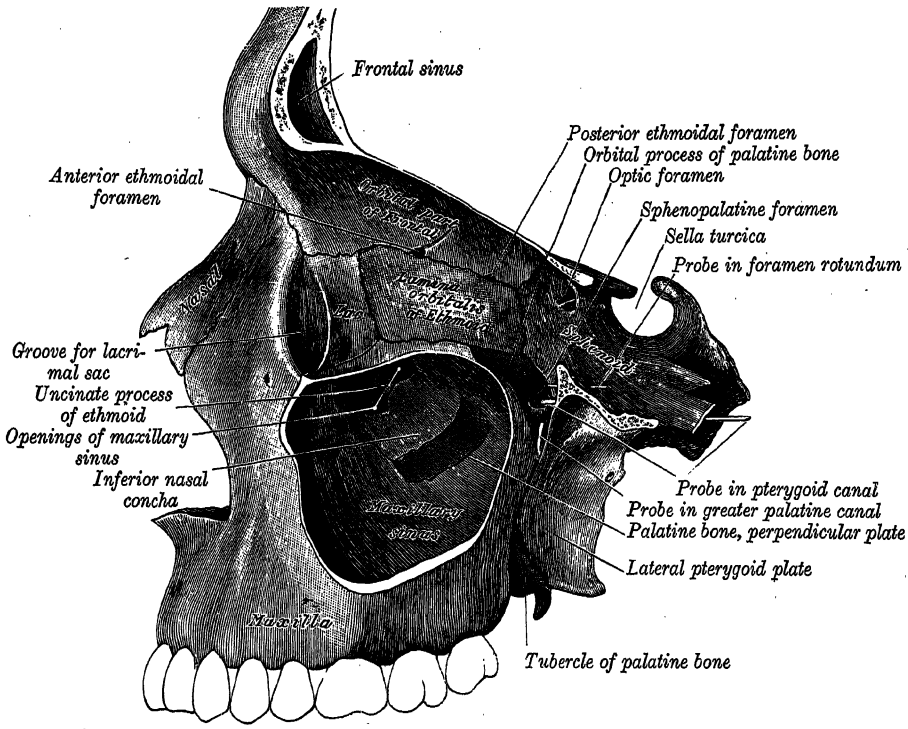
The boundaries of the **orbital opening** have already been described (p. 245). The **apex** of the orbit is at the medial end of the superior orbital fissure.

Particular features.—The roof of the orbit is formed almost entirely by the orbital plate of the frontal bone, but the under surface of the lesser wing of the sphenoid forms its posterior part. The suture between the two bones is almost horizontal. The *optic foramen* lies between the two roots of the lesser wing and is bounded medially by the body of the

sphenoid bone. Near the junction of the roof and the medial wall, and close to the orbital opening, the small *trochlear fossa* (occasionally replaced by a trochlear spine) gives attachment to the fibrous pulley through which the tendon of the superior oblique muscle of the eyeball passes.

The **medial wall** (fig. 314) is limited in front by the lacrimal crest of the frontal process of the maxilla, which gives attachment to the orbicularis oculi muscle and to the lacrimal fascia. Behind this crest the maxilla and the lacrimal bone participate in the formation of the *lacrimal groove*, and the suture between them can be seen in its floor. The upper opening of the *nasolacrimal canal* lies at the lower end of the groove, and its lateral boundary is formed by the tiny *hamulus of the lacrimal bone*, which curves forwards and medially to meet the lower part of the lacrimal crest of the frontal process of the maxilla. The posterior border of the groove is formed for the most part by the *crest of the lacrimal bone*, which gives origin to the lacrimal part of the orbicularis oculi muscle (p. 527) and to the lacrimal fascia,

FIG. 314.—The medial wall of the left orbit.



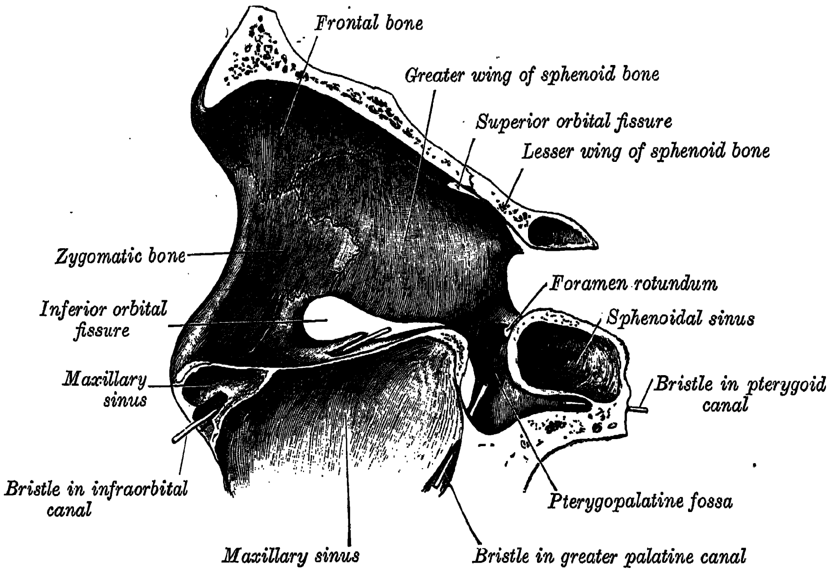
which bridges over the groove. The posterior part of the orbital surface of the lacrimal bone is flattened, and articulates behind, by an almost vertical suture, with the orbital plate of the labyrinth of the ethmoid bone. The frontolacrimal suture and the lacrimomaxillary suture indicate the other limits of the orbital aspect of the lacrimal bone. The *orbital plate of the ethmoid* makes the largest contribution to the medial wall. Almost rectangular in outline, it consists of very thin bone, which forms the lateral walls of the ethmoidal sinuses. Above, it articulates with the medial edge of the orbital plate of the frontal bone, and the line of this suture is interrupted by the *anterior* and *posterior ethmoidal foramina*, which lead into minute bony canals. These canals transmit vessels and nerves of the same names—the posterior ethmoidal nerve, however, is often absent—and lead into the anterior cranial fossa, where they open at the lateral edge of the cribriform plate. Below, the orbital plate articulates with medial edge of the orbital surface of the maxilla and, at its most posterior part, with the orbital process of the palatine bone. Posteriorly the orbital plate of the ethmoid articulates with the body of the sphenoid, which forms the most posterior part of the medial wall of the orbit and is separated from the roof by the optic foramen.

The **floor** of the orbit (fig. 313) is formed for the most part by the orbital surface of the maxilla and, in its anterolateral part, by the zygomatic bone. At its posteromedial corner, where the floor meets the medial wall, a small triangular area is formed by the orbital process of the palatine bone. In addition to the maxillary nerve the *inferior orbital fissure* transmits the infra-orbital vessels, the zygomatic nerve, and a few minute twigs from the sphenopalatine ganglion to the orbital periosteum. The fissure is bounded above by the

greater wing of the splenoid, below by the maxilla and the orbital process of the palatine bone, and laterally by the zygomatic bone or the zygomaticomaxillary suture. In from 35 to 40 per cent. of skulls the maxilla and the sphenoid bone articulate with each other at the anterior end of the fissure and exclude the zygomatic bone from it. In the anteromedial part of the floor, just lateral to the hamulus of the lacrimal bone, a small depression may mark the origin of the inferior oblique muscle from the maxilla.

The lateral wall of the orbit (fig. 315) is formed by the orbital surface of the greater wing of the sphenoid behind, and by the orbital surface of the frontal process of the zygomatic bone in front. These two bones meet at the sphenozygomatic suture. This aspect of the zygomatic bone presents the openings of minute canals for the zygomaticofacial and the zygomaticotemporal nerves. The former lies near the junction of the floor of the orbit

Fig. 315.—The lateral wall of the right orbit.



with its lateral wall; the latter lies at a slightly higher level, and may be close to the sphenozygomatic suture. The *superior orbital fissure* is bounded above by the lesser and below by the greater wing of the sphenoid and medially by the body of that bone. The lacrimal and frontal nerves traverse the narrow, lateral part of the fissure, which transmits also the meningeal branch of the lacrimal artery and the occasional orbital branch of the middle meningeal artery. The trochlear nerve is situated more medially and lies just outside the common tendinous ring. The two divisions of the oculomotor nerve, the nasociliary and the abducent nerves pass within the common tendinous ring, and therefore traverse the wider medial part of the fissure. They may be accompanied by the superior and inferior ophthalmic veins, but the superior ophthalmic veins may accompany the trochlear nerve and the inferior ophthalmic veins may pass through the medial end of the fissure below the common tendinous ring.

NORMA OCCIPITALIS

The outline of the skull, as viewed from behind, is shaped like a broad arch, being convex above and on each side, and flattened below. The *lambdoid suture*, which has already been seen in part, can now be traced through its entire length. The serrations are deep and prominent above and behind, but become much less conspicuous as the suture is traced downwards and forwards. Inferiorly the lambdoid suture meets the *occipitomastoid suture* and the *parietomastoid suture* at the posteroinferior angle of the parietal bone. The posterior portions of the parietal bones, the parietal eminences and foramina, which are visible on the norma occipitalis, have already been viewed from above.

The most outstanding feature of the norma occipitalis is the **external occipital protuberance** (fig. 316) and the ridges which lead away from it. The protuberance is situated in the lower part of the field in the median plane and may be overhanging. It can readily be identified in the living subject, as it lies at the upper end of the median furrow at the back of the neck. The *superior nuchal*

lines are the ridges, often sharp in character, which pass laterally from the protuberance. They form the boundary lines between the scalp and the back of the neck, and the portions of the occipital bone below them, now seen in perspective, will be examined in the norma basalis. The *highest nuchal lines*, when present, are curved bony ridges, which lie about 1 cm. above the superior nuchal lines. Commencing at the upper part of the protuberance they are more arched than the superior nuchal lines.

The mastoid process and the mastoid part of the temporal bone can be seen in the inferolateral part of this aspect of the skull, but they can be examined much more satisfactorily in the norma lateralis.

Particular features.—The *inion* is the name given to the most salient point on the external occipital protuberance in the median plane. The lower part of the protuberance gives attachment to the upper end of the ligamentum nuchæ, and its upper part gives origin to fibres of the trapezius muscle, which arises also from the adjoining part of the *superior nuchal line*. The lateral part of the superior nuchal line (fig. 342) gives insertion to the posterior fibres of the sternomastoid and, under cover of that muscle, to fibres of the splenius capitis. The *highest nuchal line* gives attachment medially to the epicranial aponeurosis (galea aponeurotica) and laterally to the occipital belly of the occipitofrontalis (epicranius) muscle.

NORMA LATERALIS (fig. 316)

When the skull, minus the mandible (which is described on p. 277), is examined from the side, it will be found that the anterior, superior and posterior parts have been described already in the normæ frontalis, verticalis and occipitalis, respectively. The central area, however, presents many important features which have not yet been described. It is limited above by the **temporal line**, which corresponds to the peripheral limit of the origin of the temporalis muscle. This line arches upwards and backwards from the zygomatic process of the frontal bone across the coronal suture to the parietal bone. Salient at first, it can be felt easily through the skin, but as it arches across the parietal bone it is much less distinct and is usually represented by two curved ridges, which enclose between them a smooth and often polished strip of bone. Posteriorly the upper of these two lines fades away, but the lower becomes more prominent as it curves downwards and forwards across the squamous part of the temporal bone, just above its union with the mastoid portion. This part of the line, which is termed the *supramastoid crest*, becomes continuous with the posterior root of the zygomatic process. Throughout the whole of its extent the temporal line marks the periphery of the temporalis muscle and its covering fascia. On the parietal bone the muscle arises from the lower ridge, while the fascia is attached to the upper ridge and the bone below.

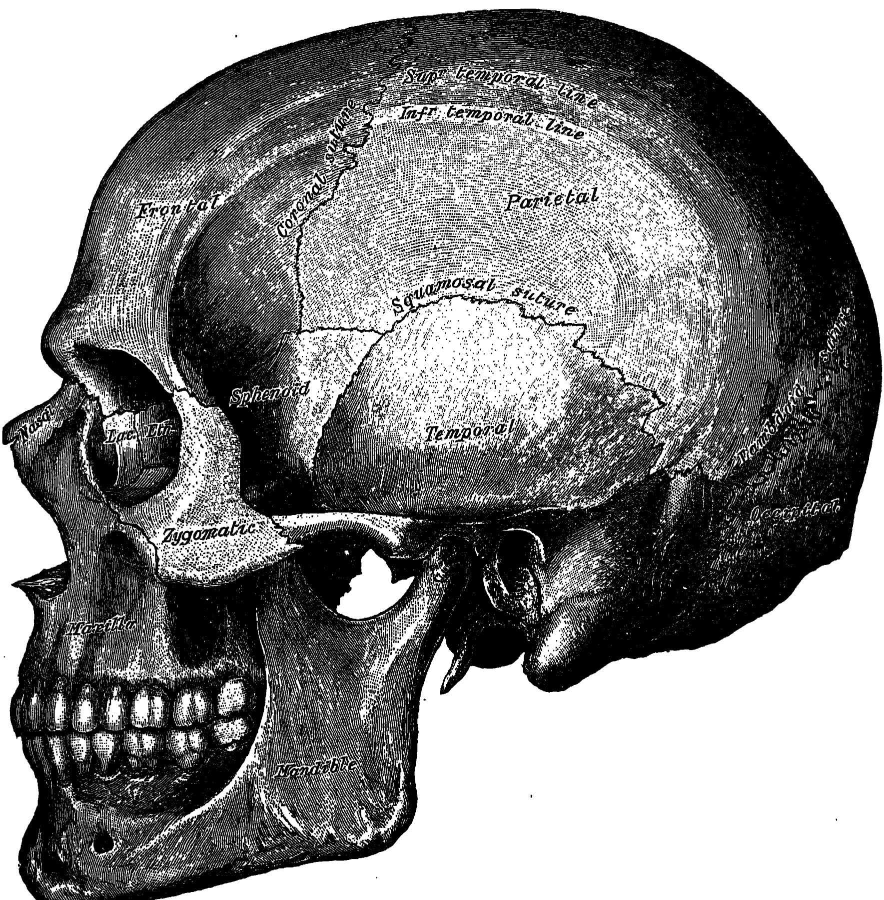
The **temporal fossa** is the region bounded by the zygomatic arch, the temporal line and the frontal process of the zygomatic bone, and its floor gives origin to the temporalis muscle. An irregularly H-shaped arrangement of sutures can be seen in the anterior part of the fossa, the more or less horizontal limb of the H being formed by the suture between the antero-inferior part of the parietal and the upper border of the greater wing of the sphenoid bone. In this situation the frontal, the sphenoid, the parietal and the squamous part of the temporal bone closely adjoin one another (fig. 316), and a small circular area can be outlined so as to include portions of all four. This area is termed the **pterion**, and its centre—which is an important landmark for the surgeon—lies 3·5 cm. behind and 1·5 cm. above the frontozygomatic suture. The anterior wall of the fossa is formed by the posterior aspect of the upper part of the zygomatic bone, the adjoining part of the greater wing of the sphenoid and a small portion of the frontal bone. It is interposed between the fossa and the orbit. Inferiorly the fossa communicates freely with the infratemporal fossa through the gap which separates the zygomatic arch from the rest of the skull. In this situation the tendon and some fleshy fibres of the temporalis descend to reach their insertion into the mandible (p. 280).

The **zygomatic arch**, which is formed by the temporal process of the zygomatic bone and the zygomatic process of the temporal bone, is easily felt through the skin where the cheek and the region of the temple meet each other. Its sharp, upper border is obscured by the attachment of the temporal fascia, and its lower border by the origin of the masseter muscle, which arises also from its deep surface. The

arch stands away from the rest of the skull and is separated from it by a gap which is deeper in front than behind. Anteriorly, the arch is crossed by the zygomatico-temporal suture, which is directed obliquely downwards and backwards.

The *zygomatic process of the temporal bone*, or *zygoma*, widens posteriorly as it approaches the squamous part, and divides into an anterior and a posterior root. The *anterior root* passes medially in front of the *articular fossa* for the head of the mandible and becomes continuous with the smooth *articular eminence*, which forms the anterior boundary of the fossa. The *posterior root* passes backwards, lateral to the fossa, and its upper border becomes continuous with the supramastoid crest of the temporal bone.

FIG. 316.—The skull. Lateral aspect. (Norma lateralis.)

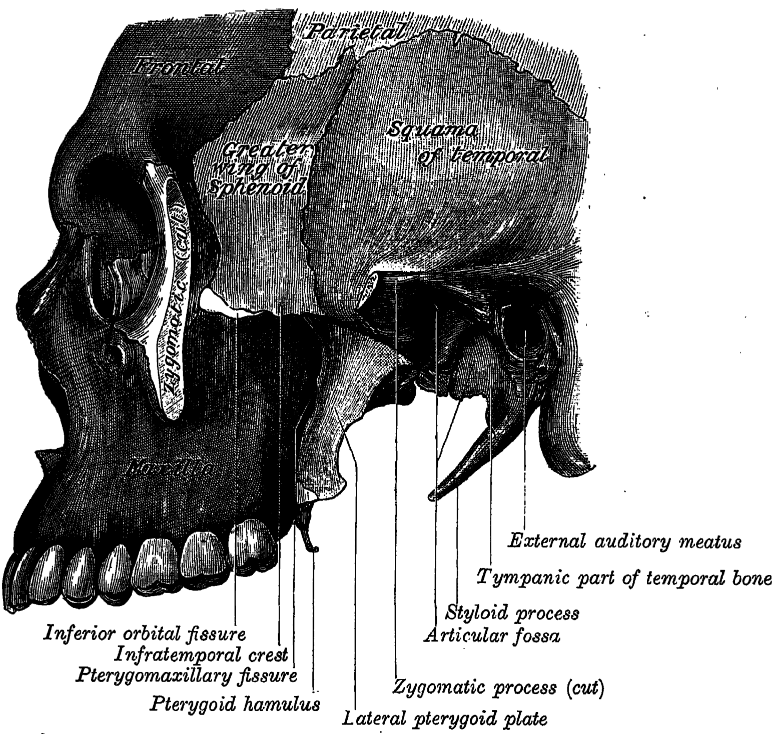


The **external auditory meatus** opens immediately below the posterior part of the posterior root of the zygoma. The margins of the orifice are roughened, especially below and in front, for the attachment of the cartilaginous segment of the meatus. The upper margin and the upper part of the posterior margin are formed by the squamous part of the temporal bone; the anterior margin, the inferior margin and the lower part of the posterior margin are formed by the *tympanic plate*. The squamotympanic suture can be seen without difficulty at the anterosuperior part of the opening, but the suture on the posterior wall is usually obliterated in the adult skull. Below the orifice of the meatus the tympanic plate is drawn downwards, forming a somewhat triangular roughened area. Immediately above and behind the meatus there is frequently a small depression with a bony spicule in its anterior margin (*suprameatal spine*). This lies within the area of the *suprameatal triangle*, which is bounded above by the supramastoid crest, in front by the postero-superior margin of the orifice of the meatus and behind by a vertical line, drawn as a tangent to the curve of the posterior margin of the meatal orifice. This triangle

forms the lateral wall of the tympanic antrum (p. 297), which is an air-space of great importance to the surgeon and is contained in the petrous part of the temporal bone.

Behind the meatus the norma lateralis is formed by the **mastoid portion of the temporal bone.** Above, it is continuous with the squamous portion in front, but, behind, it possesses a free upper border which articulates with the postero-inferior part of the parietal bone at the horizontal *parietomastoid suture.* Its posterior border is free and articulates with the squamous part of the occipital bone at the *occipitomastoid suture.* These two sutures meet each other at the lateral extremity of the lambdoid suture. The **mastoid process** (fig. 316) is a strong, nipple-shaped projection from the lower part of the mastoid portion of the temporal bone. It lies immediately behind the external auditory meatus, but at a lower level, and its anterior part can be felt through the skin under cover of the lobule of the auricle. The *mastoid foramen* pierces the bone above the base of the mastoid

FIG. 317.—The left infratemporal fossa.



process and near or on the occipitomastoid suture; it transmits an important emissary vein from the sigmoid sinus.

The **styloid process** (fig. 316) is a slender, elongated projection which, although attached to the norma basalis, can be examined conveniently at this stage. It lies a short distance in front of the mastoid process but is on a deeper plane, its base being partly ensheathed by the lower margin of the tympanic plate. Directed downwards, forwards and slightly medially, its tip is usually hidden by the posterior margin of the ramus of the mandible, when that bone is in place. From its extremity the stylohyoid ligament passes downwards and forwards to the lesser horn of the hyoid bone (p. 284), which is therefore suspended from the skull.

The **infratemporal fossa** (fig. 317) is an irregularly shaped space which lies behind the posterior surface of the maxilla. It communicates with the temporal fossa through the gap between the zygomatic arch and the side of the skull. Medial to this gap, the roof is formed by the infratemporal surface of the greater wing of the sphenoid, and a small part of the squamous temporal. In this situation the greater wing is pierced by the foramen ovale and the foramen spinosum. The medial wall is formed by the lateral pterygoid plate. These walls are con-

sidered in detail in connexion with the norma basalis (p. 258). Behind, below and on the lateral side the fossa is freely open. The anterior and medial walls meet below but they are separated above by the *pterygomaxillary fissure*, through which the infratemporal fossa communicates with the pterygopalatine fossa. The upper end of the pterygomaxillary fissure is continuous with the posterior end of the *inferior orbital fissure*, which is placed between the upper part of the posterior surface of the maxilla and the greater wing of the sphenoid. This fissure connects the infratemporal fossa with the orbit and transmits the maxillary nerve and an important venous connexion between the inferior ophthalmic vein and the pterygoid venous plexus.

The **pterygopalatine fossa** is a small pyramidal space situated below the apex of the orbit. It communicates with the infratemporal fossa through the pterygomaxillary fissure and with the orbit through the posterior end of the inferior orbital fissure. The foramen rotundum opens on its posterior wall, and the maxillary nerve, which runs forwards and laterally from the foramen across the upper part of the fossa, is the most important of its contents.

Particular features.—The floor of the *temporal fossa* is marked by a few small vascular furrows, of which the most constant are above the external auditory meatus and are produced by the middle temporal vessels. In the anterior wall of the fossa the *zygomaticotemporal foramen* pierces the temporal surface of the zygomatic bone in an upward and backward direction. It transmits the zygomaticotemporal nerve and a minute artery. In addition to the tendon of the temporalis muscle, the deep temporal vessels and nerves traverse the gap between the zygomatic arch and the rest of the skull and ascend into the temporal fossa.

As the anterior root of the zygoma springs from the process, it is marked by a small tubercle, termed the *tubercle of the root of the zygoma*. It gives attachment to fibres of the temporomandibular ligament (fig. 508) and can be felt through the skin immediately in front of the head of the mandible. Behind the articular fossa a small downward projection from the posterior root of the zygoma (sometimes termed the *post-glenoid tubercle*) meets the tympanic plate at the anterosuperior part of the orifice of the external auditory meatus, and its anterior aspect takes a small part in the formation of the articular fossa.

The posterior part of the lateral surface of the *mastoid process* and its rounded apex are roughened by the insertions of the sternomastoid, splenius capitis and longissimus capitis muscles, in that order from before backwards. In front of, and parallel to, this roughened area, the partially obliterated remains of the squamomastoid suture may be visible. From the position of the suture it will be obvious that the floor of the suprameatal triangle, and therefore the lateral wall of the tympanic antrum, is formed by the squamous part of the temporal bone. The tympanomastoid fissure is placed on the anterior aspect of the base of the process. The outer opening of the mastoid canaliculus (p. 263), which transmits the auricular branch of the vagus nerve, is placed between the lips of the fissure.

The *styloid process* is covered on its lateral aspect by the parotid gland and intervenes between that structure and the internal jugular vein. It gives origin to three muscles. The stylohyoid arises by a delicate tendon from its posterior aspect, about midway between the tip and the base; the styloglossus from the tip and the adjacent part of the anterior aspect; and the stylopharyngeus from the medial aspect of the base. The stylomandibular ligament is attached to the lateral aspect of the process in its lower part and the stylohyoid ligament to its tip. Behind the base of the process the facial nerve emerges from the stylomastoid foramen and passes forwards lateral to the process in the substance of the parotid gland.

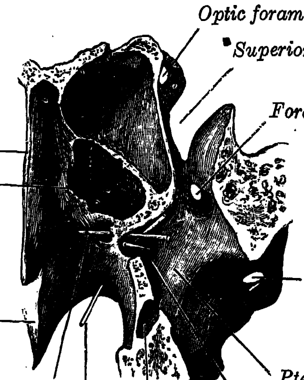
The **infratemporal fossa** (fig. 317) contains the lower part of the temporalis muscle as it passes to be inserted into the coronoid process. The maxillary (internal maxillary) artery and its branches and the pterygoid plexus of veins lie deep to the temporalis in relation to the lower head of the lateral pterygoid muscle. The deepest part of the fossa is occupied by the medial pterygoid muscle, the mandibular nerve and the chorda tympani. The mandibular nerve enters the fossa through the foramen ovale in its roof and breaks up into its terminal branches under cover of the lateral pterygoid muscle. Its branches traverse the fossa and most of them leave it to gain other regions. The chorda tympani enters the fossa on the medial side of the spine of the sphenoid and runs downwards and forwards to join the lingual nerve before it emerges at the lower border of the lateral pterygoid muscle. The maxillary nerve appears at the upper part of the fossa as it passes from the upper end of the pterygomaxillary fissure to the inferior orbital fissure. The *anterior wall* of the fossa is pierced by two or three small foramina which transmit the posterior superior dental (alveolar) vessels and nerves. It is limited below by the alveolar part of the maxilla in the region of the molar teeth, and in this situation a horizontal strip of the bone is closely covered with the mucous membrane of the gum. Immediately above this strip the bone gives origin to the upper fibres of the buccinator muscle, which extends backwards behind the last molar tooth on to the tuberosity of the maxilla. The medial wall of the fossa, formed by the lateral pterygoid plate, is completed below and in front by the tubercle

(pyramidal process) of the palatine bone, which is wedged in between the tuberosity of the maxilla and the lateral pterygoid plate. The superficial head of the medial pterygoid muscle arises from this surface of the palatine tubercle and the adjoining part of the maxillary tuberosity.

The **pterygomaxillary fissure** is a triangular interval formed by the divergence of the maxilla from the pterygoid process of the sphenoid bone. It transmits the terminal part of the maxillary (internal maxillary) artery to the pterygopalatine fossa, and its uppermost part gives passage to the maxillary nerve, which appears for a very short part of its course in the upper part of the infratemporal fossa before it enters the inferior orbital fissure. The **inferior orbital fissure** leads forwards into the orbit. Its lower border is marked by a notch which lodges the maxillary nerve and forms the posterior end of the infra-orbital groove.

The **pterygopalatine fossa** (fig. 318) is bounded above by the inferior surface of the body of the sphenoid and the orbital process of the palatine bone on the medial side, but laterally it communicates with the orbit through the posterior end of the inferior orbital fissure. It is bounded behind by the root of the pterygoid process and the adjoining part of the anterior surface of the greater wing of the sphenoid; medially, by the upper part of the

Fig. 318.—A section showing the posterior wall of the pterygopalatine fossa.



perpendicular plate of the palatine bone with its orbital and sphenoidal processes; in front, by the upper part of the posterior surface of the maxilla. On the lateral side it communicates with the infratemporal fossa through the pterygomaxillary fissure, and inferiorly its anterior and posterior walls come into apposition. The fossa contains the maxillary nerve, the sphenopalatine ganglion and the terminal part of the maxillary (internal maxillary) artery. In addition to the pterygomaxillary and inferior orbital fissures five openings lead to or from the fossa. Of these, three are situated on the posterior wall, viz., the foramen rotundum, the pterygoid canal and the palatinovaginal (pharyngeal) canal, in that order downwards and medially. The *foramen rotundum* transmits the maxillary nerve from the middle cranial fossa; the *pterygoid canal*, the nerve and artery of the same name from the lower part of the anterior wall of the foramen lacerum; and the *palatinovaginal* (pharyngeal) *canal*, which is frequently double (p. 260), the pharyngeal nerve and artery to the roof of the posterior nasal aperture. The fourth foramen is placed on the medial wall and is termed the *sphenopalatine foramen* (fig. 329). It is bounded above by the body of the sphenoid, in front by the orbital process of the palatine bone, behind by the sphenoidal process and below by the upper border of the perpendicular plate. It transmits the long and short sphenopalatine nerves (nasopalatine and posterior superior lateral nasal nerves) and the artery of the same name. The fifth foramen is placed inferiorly at the junction of the anterior and posterior walls, and leads into the *greater palatine canal* (pterygopalatine canal). Bounded anterolaterally by the maxilla, and posteromedially by the perpendicular plate of the palatine bone, this canal transmits the greater and lesser palatine nerves and vessels, which appear at the greater and lesser palatine foramina on the bony plate (p. 256).

NORMA BASALIS (BASIS CRANII EXTERNA), (figs. 319–322)

The external surface of the base of the skull, excluding the mandible, is bounded in front by the incisor teeth of the maxillæ, behind by the superior

nuchal lines of the occipital bone, and laterally by the remaining teeth, the zygomatic arch and its posterior root, and the mastoid process. It is very irregular and, unlike the internal surface, shows no natural subdivision into regions suitable for descriptive purposes. It is, however, useful to divide the area into anterior, middle and posterior parts. The anterior part, which is formed by the hard palate and the alveolar arches is on a lower level than the part behind. The remainder of the surface is divided, in an arbitrary manner, into a middle and a posterior part by a transverse line drawn through the anterior margin of the foramen magnum.

FIG. 319.—The external surface of the left half of the base of the skull. (Norma basalis.)

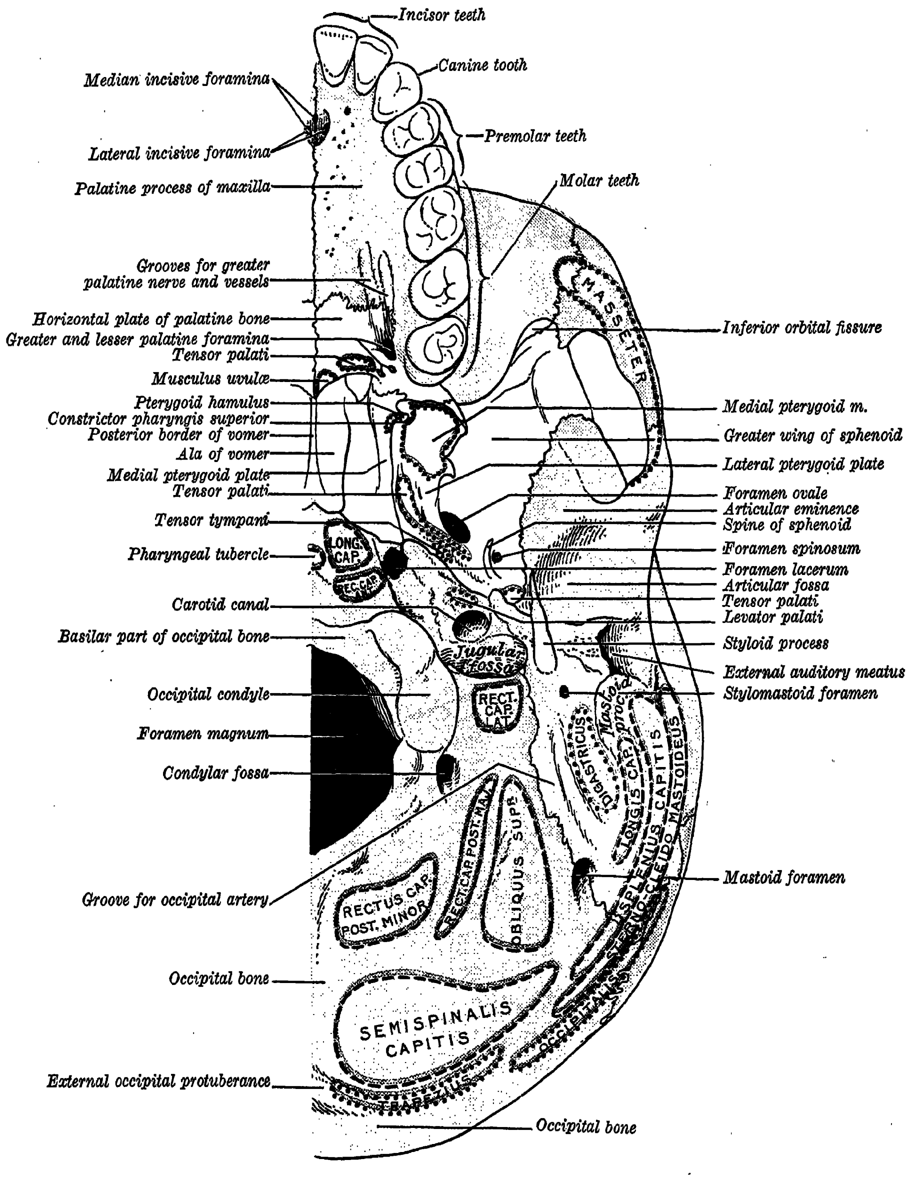
The Anterior Part of the Norma Basalis

The **bony palate** (fig. 321) lies within the arch formed by the teeth of the maxillæ and the alveolar processes. It is formed by the palatine processes of the maxillæ and the horizontal plates of the palatine bones, which are separated from one another by a cruciform suture, made up of the intermaxillary, interpalatine and palatomaxillary sutures. Owing partly to the downward projection of the alveolar arches, the palate is arched both from before backwards and from side to side. The depth and the breadth of the palatine vault are subject to considerable variation but are always greatest in the region of the molar teeth. A deep fossa, termed the *incisive fossa*, lies in the median plane anteriorly. The *lateral incisive foramina*, which lead into the incisive canals, are situated in its lateral walls; the *median incisive foramina*, which are present in some skulls, open on its anterior and posterior walls. The *greater palatine foramen*, which is the lower orifice of the canal of the same name, opens close to the lateral border of the palate immediately behind the palatomaxillary suture. A vascular groove, deep behind and becoming shallower in front, leads forwards away from the foramen. The *lesser palatine foramina*, usually two in number, are situated behind the greater foramen. They pierce the *tubercle* (pyramidal process) *of the palatine bone*, which projects backwards and laterally from the posterolateral corner of the bony palate and becomes wedged into the notch between the lower ends of the two pterygoid plates. The vault of the bony palate is uneven, pierced by numerous small foramina and marked by depressions for the palatine glands. Near the posterior border it presents a slightly curved ridge of variable prominence, termed the *palatine crest*, which commences behind the greater palatine foramen and runs medially. The posterior

border of the bony palate is free and projects backwards in the median plane to form the *posterior nasal spine.*

The *alveolar arch* provides sixteen sockets (alveoli) for the roots of the teeth. These sockets vary in size and depth and are single or subdivided by septa according to the teeth which they contain.

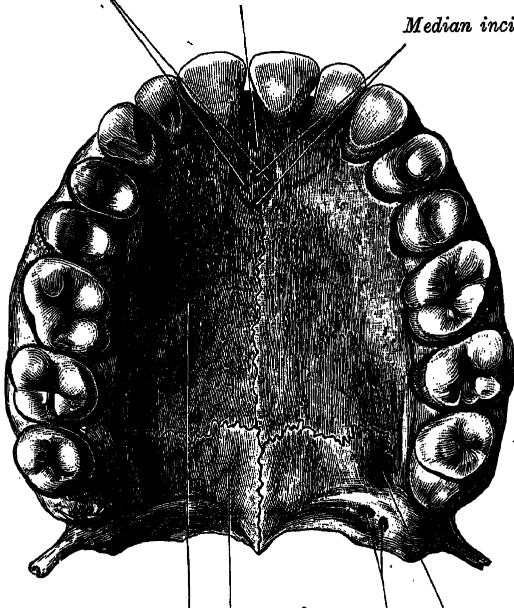
Fig. 320.—Key to fig. 319.



Particular features.—The *lateral incisive foramen* transmits the terminal branches of the greater palatine vessels and the long sphenopalatine (nasopalatine) nerve. When median incisive foramina are present the left sphenopalatine nerve passes through the anterior and the right through the posterior foramen. The lateral incisive foramina are placed in the line of fusion of the os incisivum (premaxilla) with the maxilla proper, and represent a primitive communication between the mouth and the nose. In young skulls the suture line between the os incisivum and the maxilla may be visible, extending from the posterior part of the incisive fossa to the septum between the sockets of the lateral incisor and canine teeth. The *greater palatine foramen* transmits the greater palatine nerve and vessels, and

the vessels groove the lateral part of the palate as they run forwards to the incisive fossa. The *lesser palatine foramina*, usually two, sometimes one and occasionally three in number, perforate the inferior and medial aspects of the tubercle of the palatine bone; they transmit the lesser palatine nerves. The *palatine crest*, which commences on the tubercle and extends on to the horizontal plate of the palatine bone, gives attachment to part of the tendon of the tensor palati muscle. The free posterior border of the bony palate gives attachment to the palatine aponeurosis and the posterior nasal spine to the musculus uvulæ.

Fig. 321.—The bony palate and the alveolar arch. Inferior aspect.



The Middle Part of the Norma Basalis

The middle part of the external surface of the base of the skull (fig. 319) extends from the posterior border of the bony palate to an arbitrary line drawn transversely through the anterior margin of the foramen magnum. In the median plane anteriorly the *posterior border of the vomer* separates the two *posterior nasal apertures*. Immediately behind the vomer the posterior part of the inferior surface of the body of the sphenoid is directly continuous with the inferior surface of the *basilar part of the occipital bone*, which forms a broad bar of bone extending backwards and downwards to the foramen magnum. It is convex from side to side and wider behind than in front. A short distance in front of the foramen magnum it is marked in the median plane by a small elevation, termed the *pharyngeal tubercle*, which gives attachment to the highest fibres of the superior constrictor muscle of the pharynx.

Behind the third molar tooth the **pterygoid process** descends from the junction of the greater wing and the body of the sphenoid bone. It has two laminæ, termed the medial and lateral pterygoid plates, which are separated from each other by a V-shaped interval, directed backwards and somewhat laterally and named the *pterygoid fossa*. Anteriorly the two pterygoid plates are fused to each other, except inferiorly, where they are separated by a narrow gap which is occupied in the articulated skull by the *tubercle* (pyramidal process) of the palatine bone, and the suture lines can usually be identified. Above the pterygoid fissure the two plates are fused to each other On the medial side they articulate with the posterior border of the perpendicular plate of the palatine bone in front, and form with it the flattened

area of bone which lies in the lateral wall of the posterior nasal aperture and nasal part of the pharynx. On the lateral side the fused laminæ are separated from the posterior surface of the maxilla in front by the pterygomaxillary fissure (fig. 249). The *medial pterygoid plate* is the narrower of the two and projects directly backwards. Its medial surface is covered in the recent state with mucous membrane and forms the lateral boundary of the posterior nasal aperture and part of the lateral wall of the nasal part of the pharynx. The posterior border of the medial pterygoid plate is thin and sharp, and presents a small projection about its midpoint. Above this projection the border is curved and is attached to the pharyngeal end of the pharyngotympanic (auditory) tube. At its upper end the border divides to enclose the shallow, *scaphoid fossa* (fig. 323); below, it projects beyond the rest of the plate as the slender *pterygoid hamulus*. This process curves downwards and laterally and is grooved anteriorly at its root by the tendon of the tensor palati muscle. The *lateral pterygoid plate* projects backwards and laterally and its lateral surface forms the medial wall of the infratemporal fossa. Superiorly it is continuous with the *infratemporal surface of the greater wing of the sphenoid*, which forms the anterior part of the roof of the infratemporal fossa. This surface of the greater wing is directed downwards and, sometimes, slightly to the lateral side. It is roughly pentagonal; its anterior margin forms the posterolateral border of the inferior orbital fissure; and in front and to the lateral side it is limited by the infratemporal crest. Laterally it articulates with the squama of the temporal bone; medially it is continuous with the root of the pterygoid process and the side of the body of the sphenoid; and posteromedially it articulates with the petrous part of the temporal bone.

Two important foramina open on the infratemporal surface of the greater wing of the sphenoid. The **foramen ovale**, irregularly oval in outline, lies close to the posterior border and posterolateral to the upper end of the posterior margin of the lateral pterygoid plate. It transmits the mandibular division of the trigeminal nerve. Posterior and slightly lateral to the foramen ovale the **foramen spinosum** pierces the greater wing and transmits the middle meningeal artery to the middle cranial fossa. It is much smaller than the foramen ovale and is circular in outline. Immediately posterolateral to the foramen spinosum the posterolateral angle of this surface of the greater wing forms an irregular downward projection, termed the *spine of the sphenoid*. The medial surface of the spine is flattened, and together with the adjoining part of the posterior border of the greater wing forms the anterolateral border of a groove which is completed on the posteromedial side by the petrous part of the temporal bone. This groove lodges the cartilaginous part of the pharyngotympanic (auditory) tube, and leads backwards into the canal for the tube in the petrous part of the temporal bone and forwards to the upper part of the posterior border of the medial pterygoid plate. In the roof of the groove the posterior border of the greater wing and the anterior border of the petrous temporal come into apposition with each other. It will be apparent that immediately below the skull the mandibular nerve and the middle meningeal artery must be related to the anterolateral aspect of the pharyngotympanic tube.

Behind and medial to the groove for the tube the *inferior surface of the petrous temporal* occupies the interval between the infratemporal surface of the greater wing of the sphenoid and the basilar part of the occipital bone. The anterior part of this surface is rough and uneven, and its apex is separated from the posterolateral part of the body of the sphenoid by an irregular bony canal, termed the *foramen lacerum*. Behind this rough area a large and approximately circular foramen leads upwards into the bone. It is the lower opening of the *carotid canal*, which is traversed by the internal carotid artery. Within the bone the canal turns forwards and medially and opens on the posterior wall of the foramen lacerum. After passing through the canal the artery turns upwards to gain the interior of the skull. The lower part of the foramen lacerum is occupied in the recent state by fibrocartilage, and no large structure enters or leaves the skull through this opening.

Lateral to the base of the spine of the sphenoid the *squamotympanic fissure* runs laterally and slightly backwards between the upper part of the tympanic plate and the articular fossa of the squamous part of the temporal bone. The fissure can usually be traced to the upper part of the anterior margin of the orifice of the external auditory meatus, but it is sometimes obliterated near its lateral end. The *articular fossa* is deeply concave from before backwards and gently concave from

side to side, and is wider at its lateral than at its medial head. It lodges the head of the mandible when the mouth is closed. Anteriorly the articular surface passes on to a transverse rounded elevation, termed the *articular eminence*, which is continuous laterally with the anterior root of the zygoma. In front it becomes continuous with the part of the squamous temporal which lies in the roof of the infratemporal fossa. Behind the squamotympanic fissure the *tympanic part of the temporal bone* separates the articular fossa from the external auditory meatus. This part of the temporal bone is roughly triangular in outline, the apex being situated at the medial end of the squamotympanic fissure close to the root of the spine of the sphenoid. Its lower border is free and skirts the anterolateral margin of the lower opening of the carotid canal, extending backwards and laterally to reach the root of the styloid process. There it forms the *sheath of the styloid process*, which is longer and more apparent on the lateral than on the medial side. At its lateral margin the tympanic part is fused with the mastoid part of the temporal bone below and is free above, where it forms the anterior border of the orifice of the external auditory meatus.

Particular features.—The upper border of the *vomer*, which is applied to the inferior surface of the body of the sphenoid, is expanded into an *ala* on each side (fig. 319), and the groove between the alæ receives the *rostrum of the sphenoid*. The lateral border of each ala comes into relation with a thin lamella which projects medially from the root of the medial pterygoid plate and is termed the *vaginal process*. The two may come merely into contact or the edge of the ala may extend into the narrow interval between the body of the sphenoid above and the vaginal process below. The inferior surface of the vaginal process is marked by an anteroposterior groove, which is converted into a canal anteriorly by the upper surface of the sphenoidal process of the palatine bone. This canal is termed the *palatinovaginal (pharyngeal) canal* and opens anteriorly through the posterior wall of the pterygopalatine fossa. It transmits the pharyngeal branch of the sphenopalatine ganglion and a minute pharyngeal branch from the third part of the maxillary (internal maxillary) artery. A second canal may be present in this situation on the medial side of the palatinovaginal canal. It lies between the ala of the vomer and the upper surface of the vaginal process and is termed the *vomerovaginal canal*. When present it leads forwards into the anterior end of the palatinovaginal canal.

In front of the pharyngeal tubercle the *inferior surface of the basilar part of the occipital bone* is intimately related to the roof of the nasal pharynx and the nasopharyngeal tonsil. Lateral to the tubercle the bone receives the insertion of the longus capitis muscle, and the area extends forwards on each side beyond the tubercle. Behind the longus capitis the rectus capitis anterior is inserted into the bone in front of the occipital condyle and medial to the outer opening of the anterior condylar (hypoglossal) canal.

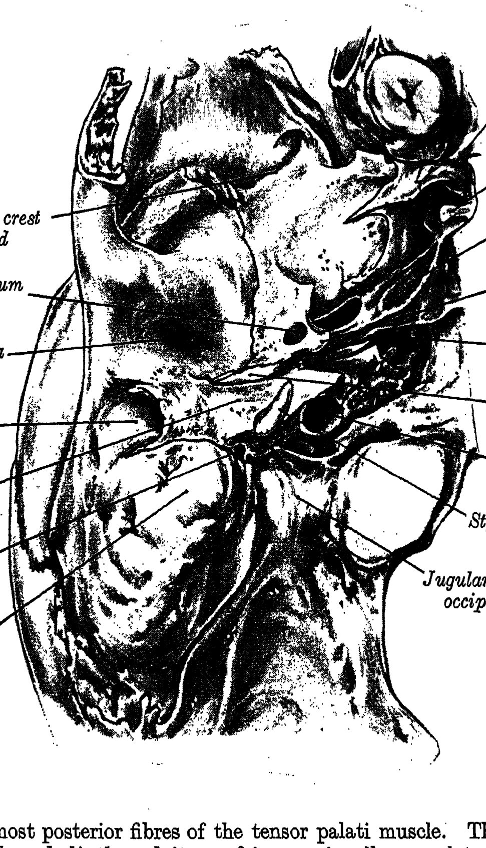
The medial surface of the **medial pterygoid plate** (fig. 328) is smooth and covered with the mucous membrane of the nasal pharynx in the recent state. At the upper part of its posterior border the *scaphoid fossa* gives origin to the anterior fibres of the tensor palati muscle, which descends along the lateral surface and posterior border of the plate to reach the *hamulus*. The tendon of the muscle twists medially round the lateral and anterior aspects of the process to gain the soft palate. The posterior border of the medial pterygoid plate, notched above by the pharyngotympanic (auditory) tube (p. 259), gives attachment to the pharyngobasilar fascia. Its lower part and the posterior aspect of the hamulus give origin to the highest fibres of the superior constrictor muscle of the pharynx, which curve upwards and medially to be inserted into the pharyngeal tubercle. The tip of the hamulus gives attachment to the pterygomandibular ligament (raphe). At its upper end the posterior border of the medial pterygoid plate is marked by a small tubercle, which lies on the medial side of the scaphoid fossa. This tubercle projects backwards below, and conceals the posterior opening of the *pterygoid canal*, which leads forwards to open on the posterior wall of the pterygopalatine fossa. It transmits the nerve and vessels of the pterygoid canal and lies in the line of fusion of the pterygoid process and greater wing with the body of the sphenoid bone.

The *pterygoid fossa* lies between the opposed surfaces of the two pterygoid plates and is completed below and in front by the tubercle (pyramidal process) of the palatine bone. The lateral wall of the fossa gives origin to the deep head of the medial pterygoid muscle. The **lateral pterygoid plate** (fig. 317) is a wider lamina than the medial plate, and its irregular posterior border may present a backward projection, termed the *pterygospinous process*, which is connected by a ligament (sometimes ossified) to the spine of the sphenoid. The lateral surface, which is the rougher of the two, gives origin to the lower head of the lateral pterygoid muscle; the medial surface gives origin to the deep head of the medial pterygoid muscle. The lateral aspect of the *tubercle (pyramidal process) of the palatine bone*, which appears between the tuberosity of the maxilla and the lower part of the lateral pterygoid plate, gives origin to some fibres of the superficial head of the medial pterygoid muscle.

The *infratemporal surface of the greater wing of the sphenoid* gives origin to the upper head

of the lateral pterygoid muscle, and is crossed by the deep temporal and the masseteric nerves, which run between the muscle and the bone. In addition to the mandibular nerve the **foramen ovale** transmits the accessory meningeal artery. Its posterior border is thin and sharp and gives origin to fibres of the tensor palati muscle, which intervenes between the mandibular nerve and the pharyngotympanic (auditory) tube. The **foramen spinosum** transmits the small nervus spinosus in addition to the middle meningeal artery. In the interval between the foramen ovale and the scaphoid fossa the bone sometimes presents a small foramen, termed the *emissary sphenoidal foramen* (foramen Vesalii), which transmits an emissary vein from the cavernous sinus. The *spine of the sphenoid*, which varies greatly in size, and may be sharply pointed or may be blunt at its extremity, gives attachment to the sphenomandibular ligament. It is related laterally to the auriculotemporal nerve and medially to the chorda tympani—by which its medial aspect is sometimes grooved—and to the pharyngotympanic tube. Anteriorly it gives

FIG. 322.—A portion of the norma basalis of the right side.



origin to the most posterior fibres of the tensor palati muscle. The groove for the tube varies in width and depth and its roof is occasionally completed by membrane. The lateral or sphenoidal wall of the groove gives origin, posteriorly, to fibres of the tensor tympani muscle.

The lateral part of the rough inferior surface of the petrous part of the temporal bone gives origin to the levator palati muscle. The **foramen lacerum** is bounded in front by the posterolateral part of the body of the sphenoid and the adjoining roots of the pterygoid process and greater wing; behind and laterally by the apex of the petrous part of the temporal bone; and medially by the basilar part of the occipital bone. It forms a canal nearly 1 cm. long, but no large structure passes through its whole length. The anterior orifice of the carotid canal opens on its posterior wall, and the vessel with its plexus of veins and its plexus of sympathetic nerves ascends through the upper end of the canal. In the foramen the deep petrosal nerve from the carotid sympathetic plexus is joined by the greater superficial petrosal nerve to form the nerve of the pterygoid canal, and this canal opens on the lower part of the anterior wall. Meningeal branches of the ascending pharyngeal artery, emissary veins from the cavernous sinus and a few meningeal lymphatics traverse the whole length of the foramen. The cartilage which fills its lower part is a remnant of the primitive chondrocranium.

The floor of the *articular fossa* is very thin and corresponds to the most lateral part of the floor of the middle cranial fossa. It is covered in the recent state by white fibrocartilage. The *tubercle of the root of the zygoma* gives attachment to the temporomandibular ligament. A thin edge of bone may be visible in the depths of the medial end of the *squamotympanic fissure*. It is the lower border of the down-turned lateral portion of the tegmen tympani and therefore is a part of the petrous temporal. It divides the upper part of the squamotympanic fissure into a petrotympanic and a petrosquamous fissure. Through the petrotympanic fissure the chorda tympani travels in its anterior canaliculus, as it passes downwards and forwards from the tympanic cavity. The anterior tympanic artery from the maxillary artery also traverses the petrotympanic fissure.

The **tympanic part of the temporal bone** (fig. 322) is separated from the capsule of the temporomandibular joint by a portion of the parotid gland, which is intimately related to the auriculotemporal nerve. It is thinnest near the centre of this surface and is occasionally deficient in this situation (p. 302). The grooved upper aspect of the plate forms the anterior wall, the floor and the lower part of the posterior wall of the external auditory meatus. Except where it ensheathes the styloid process its posterior surface is fused with the petrous part of the bone.

The Posterior Part of the Norma Basalis (fig. 319)

The median portion of the posterior subdivision of the external surface of the base of the skull is occupied in front by the **foramen magnum** of the occipital bone, which leads into the posterior cranial fossa. The foramen is oval in shape and its anteroposterior measurement exceeds its transverse. The curve of its margin is wider behind than in front. It transmits a large number of structures of which the most important is the lower end of the brain-stem. Anteriorly the margin of the foramen magnum is overlapped slightly on each side by the *occipital condyle*, which projects downwards to articulate with the superior articular facet on the lateral mass of the atlas. Oval in outline, the condyle is placed obliquely so that its anterior end is nearer the median plane than its posterior end. It shows a pronounced convexity from before backwards and a gentle convexity from side to side. The medial aspect is roughened for ligamentous attachments. Above the anterior part of the condyle the occipital bone is pierced by the *anterior condylar* (*hypoglossal*) *canal*, which runs laterally and slightly forwards from the posterior cranial fossa and transmits the hypoglossal nerve.

A depression of variable depth marks the occipital bone behind the condyle. It is termed the *condylar fossa*, and may be pierced by the *posterior condylar canal*, which, when present, transmits an emissary vein from the sigmoid sinus. Lateral to the condyle the *jugular process of the occipital bone* articulates with the petrous temporal. The anterior border of the process is free and forms the posterior boundary of the **jugular foramen**. This large foramen lies between the occipital bone and the jugular fossa of the petrous temporal and is placed at the posterior end of the petro-occipital suture. In front it is separated from the lower orifice of the carotid canal by a raised ridge of bone, and on its lateral side it is related to the medial aspect of the sheath of the styloid process. Medially it is separated from the anterior condylar canal by a thin bar of bone. The foramen is usually larger on the right side of the skull and its long axis is directed forwards and medially. The anterior part of the foramen transmits the inferior petrosal sinus; its intermediate part, the glossopharyngeal, vagus and accessory nerves; and its posterior part the internal jugular vein. When the superior bulb of the internal jugular vein is well developed the *jugular fossa of the temporal bone* is hollowed out in an upward and lateral direction to accommodate it.

The *styloid process* has been described already (p. 253). Posterior to its root the *stylomastoid foramen* transmits the facial nerve. Behind and lateral to the foramen the tip of the *mastoid process* projects downwards and forwards, and forms the lateral wall of the *mastoid* (digastric) *notch*, from which the posterior belly of the digastric muscle takes origin. Medial to the notch the mastoid part of the temporal bone may be grooved by the occipital artery.

In the median plane behind the foramen magnum the squamous part of the occipital bone presents the *external occipital crest*, which gives attachment to the upper end of the ligamentum nuchæ. It terminates behind at the external occipital protuberance. Near its midpoint the *inferior nuchal line* begins and curves backwards and laterally. It is nearly parallel to the *superior nuchal line*, which extends

in the same direction from the external occipital protuberance and may be raised into a distinct crest in its medial part.

Particular features.—The **foramen magnum** provides a wide communication between the posterior cranial fossa and the vertebral canal. Anteriorly it transmits the apical ligament of the odontoid process (dens) and the membrana tectoria, both of which gain attachment to the upper surface of the basilar part of the occipital bone. Its wider, posterior part transmits the lower end of the medulla oblongata and the meninges. In the subarachnoid space the spinal roots of the accessory nerves, and the vertebral arteries, with their plexuses of sympathetic nerves, ascend to gain the interior of the cranium, the posterior spinal arteries descend, one on each posterolateral aspect of the brain stem, and the anterior spinal artery descends on the front of the brain stem in the median plane. In addition, the lower parts of the tonsils of the cerebellum may project into the foramen on each side of the medulla oblongata. The *anterior margin* of the foramen gives attachment to the anterior atlanto-occipital membrane, which is continuous on each side with the capsular ligament of the atlanto-occipital joint. The *posterior margin* gives attachment to the posterior atlanto-occipital membrane, and the roughened medial aspect of the *condyle* to the alar ligament.

In addition to the hypoglossal nerve the *anterior condylar* (*hypoglossal*) *canal* transmits a meningeal branch of the ascending pharyngeal artery and a small emissary vein from the basilar plexus. Not uncommonly the canal is divided into two parts by a spicule of bone, a variation which is in keeping with the composite origin of the hypoglossal nerve. The inferior surface of the jugular process of the occipital bone provides insertion for the rectus capitis lateralis muscle.

The **jugular foramen** (fig. 319) is directed upwards, medially and backwards, and on the external surface of the base of the skull its apparent size is increased owing to the presence of the jugular fossa of the temporal bone on its lateral side. The floor of the fossa separates the superior bulb of the internal jugular vein from the tympanic cavity, and its lateral wall is pierced by a minute canal, termed the *mastoid canaliculus*, which transmits the auricular branch of the vagus nerve. Passing laterally through the bone this nerve comes into intimate relationship with the facial canal and finally emerges in the line of the tympanomastoid suture. It is extra-cranial at birth but becomes surrounded by bone as the tympanic plate and the mastoid process develop. On or near the ridge between the jugular fossa and the orifice of the carotid canal, the *canaliculus for the tympanic nerve* pierces the bone to transmit the tympanic nerve from the glossopharyngeal nerve to the middle ear. On the upper boundary of the jugular foramen near its medial end, there is a small notch—more easily identified on the internal surface—which lodges the inferior (petrous) ganglion of the glossopharyngeal nerve. The orifice of the *cochlear canaliculus* (p. 299) lies at the apex of the notch, the projecting edges of which may reach the occipital bone and divide the foramen into three parts.

The *stylomastoid foramen* lies behind the root of the styloid process and at the anterior end of the mastoid notch. As the facial nerve emerges from the foramen it is in close proximity to the posterior belly of the digastric, which it supplies before entering the parotid gland. In addition to the facial nerve the foramen transmits the stylomastoid branch of the posterior auricular artery. A vascular groove crosses the inferior aspect of the mastoid part of the temporal bone medial to the mastoid notch. It is caused by the occipital artery, and its absence indicates that the vessel lay at a lower level than usual and between the splenius capitis and longissimus capitis instead of deep to both muscles.

The area below the *inferior nuchal line* gives insertion medially to the rectus capitis posterior minor, and laterally to the rectus capitis posterior major (fig. 342). The interval between the inferior and the superior nuchal lines provides insertion medially for the semispinalis capitis and laterally for the obliquus superior. In its medial part the *superior nuchal line* gives origin to the highest fibres of the trapezius muscle; in its lateral part it gives insertion to fibres of the sternomastoid and, more anteriorly, splenius capitis.

THE INTERIOR OF THE SKULL

The **cranial cavity** contains the brain and its membranes and their blood-vessels. Its walls are formed by the frontal, parietal, sphenoid, temporal and occipital bones and, to a very small extent, by the ethmoid bone. They are lined with a fibrous membrane, termed the *endocranium*, which is the outer layer of the dura mater. It passes through the various foramina which lead to the exterior, and becomes continuous with the periosteum on the outer surfaces of the bones of the skull, often termed the *pericranium*. Both these fibrous membranes are continuous with the sutural ligaments, which occupy the narrow interosseous intervals at the sutures.

The walls of the cranial cavity vary in thickness in different skulls and in different parts of the same skull; but they tend to be thinner in situations where they

are well covered with muscles externally, e.g. the temporal and posterior cranial fossæ. Most of the cranial bones consist of an *outer* and an *inner table*, formed of compact substance and separated from each other by the *diploë*, which consists of spongy substance containing red bone marrow in its interstices. Many of the bones are so thin that the two tables are continuous, e.g. the vomer, pterygoid plates, etc. The inner table is thinner and more brittle than the outer table, which is often surprisingly resilient.

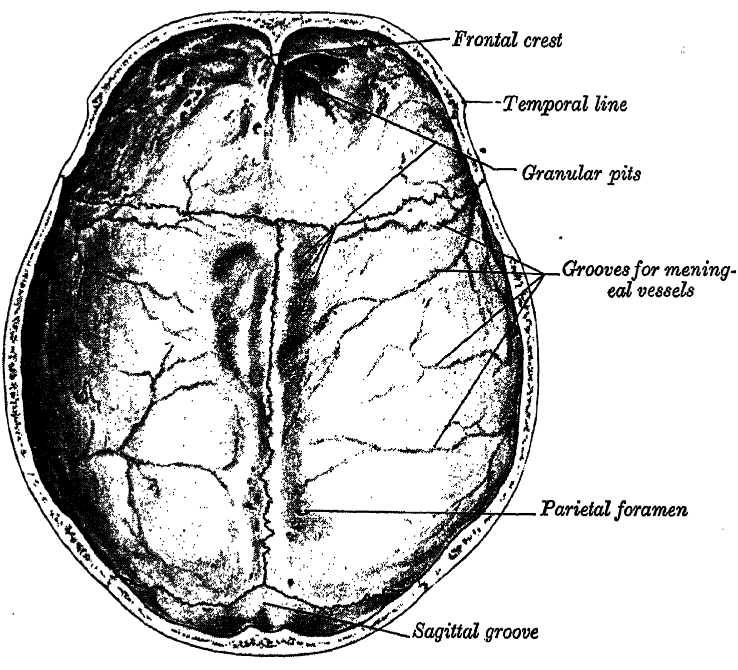
Although the skull tends to be thicker in primitive than in higher races no relationship exists between thickness of skull and mental capacity, and in all races the bones of the skull are thinner in women and children than in men.

The interior of the skull is described in two sections: (1) the internal surface of the skull-cap; and (2) the internal surface of the base of the skull.

The Internal Surface of the Skull-Cap (fig. 323)

The skull-cap comprises most of the frontal and parietal bones and the uppermost portion of the squamous part of the occipital bone. It is marked, therefore,

Fig. 323.—The internal surface of the skull-cap.



by the coronal, sagittal and lambdoid sutures, but they may or may not be visible for the cranial sutures tend to become obliterated in old age and the process commences on the cerebral surface. The skull-cap is deeply concave in all directions and presents numerous vascular furrows and other markings.

Anteriorly, in the median plane, the upper end of the *frontal crest* projects backwards. It gives attachment to the falx cerebri and is grooved by the commencement of the *sagittal sulcus*. This sulcus lodges the superior sagittal sinus, and widens progressively as it runs backwards in the median plane along the sagittal suture to the occipital bone. On each side of the sagittal sulcus the bone presents a number of irregular depressions, termed *granular pits*. They are more numerous and more obvious in aged skulls and are formed by the arachnoid granulations, which are tuft-like protrusions of the arachnoid mater.

The anterior branch of the middle meningeal artery grooves the bone deeply about 1 cm. behind the coronal suture, and its line corresponds more or less accurately to the precentral sulcus of the cerebrum. Its rami and those of the posterior branch of the same artery course upwards and backwards from the cut edge of the

skull-cap, grooving the inner surface of the parietal bone. Smaller grooves produced by meningeal vessels may be present on the inner surfaces of the frontal and occipital bones. When present, the *parietal foramina* open on this surface near the sagittal groove about 3·5 cm. in front of the lambdoid suture. Each transmits an emissary vein from the superior sagittal sinus.

The *impressions for the cerebral gyri* are less distinct on the skull-cap than on the base of the skull and are seen best near the cut edge.

The Internal Surface of the Base of the Skull [Basis Cranii Interna] (figs. 324, 325)

The internal surface of the base of the skull shows a natural subdivision into anterior, middle and posterior cranial fossæ. It is very irregular owing, partly, to the impressions for the cerebral gyri, which are especially conspicuous in the anterior and middle fossæ, where they reflect accurately the pattern of the surface of the corresponding parts of the cerebrum. The dura mater is firmly adherent to the whole area, and through the numerous foramina and fissures the endocranium is continuous with the periosteum on the exterior of the skull (pericranium).

The Anterior Cranial Fossa (figs. 324, 325)

The **anterior cranial fossa** is limited in front and on each side by the frontal bone. Its floor is formed by the orbital plates of the frontal bone, the cribriform plate of the ethmoid and the lesser wings and anterior part of the body of the sphenoid.

The *cribriform plate of the ethmoid*, which stretches across the median plane, lies between the two orbital plates of the frontal bone, and is depressed below the level of the rest of the floor. It separates the fossa from the nasal cavity, the roof of which it helps to form (fig. 330). Anteriorly it presents a median crest-like elevation, termed the *crista galli*, which projects upwards between the two cerebral hemispheres. A depression intervenes between the front of the crista galli and the *crest of the frontal bone*, the floor of which is crossed by the fronto-ethmoidal suture and is marked by the presence of the *foramen cæcum*. On each side the crista galli is separated from the orbital plate of the frontal bone by a narrow interval. The numerous small foramina which perforate the cribriform plate transmit the minute olfactory nerves from the nasal mucosa to the olfactory bulb. Posteriorly the cribriform plate articulates with the anterior part of the body of the sphenoid at the spheno-ethmoidal suture.

The *orbital plate of the frontal bone* forms the greater part of the floor of the fossa on each side of the median plane and separates the orbit and its contents from the inferior surface of the frontal lobe of the brain. Its surface is convex upwards and is marked by impressions for the cerebral gyri and by one or two small grooves for meningeal vessels. In its anteromedial part it is split into two laminæ to contain part of an air-space, termed the *frontal sinus*. The medial part of the orbital plate covers the ethmoidal labyrinth and shuts it out from the floor of the anterior cranial fossa. Posteriorly it articulates with the anterior border of the *lesser wing of the sphenoid bone*. In the median plane the cerebral surface of the frontal bone is marked by the *frontal crest*, which projects backwards into the interval between the two cerebral hemispheres and extends upwards on to the interior of the skull-cap.

Behind the cribriform plate the floor of the anterior cranial fossa is formed by the anterior portion of the upper surface of the body of the sphenoid. This part of the bone is termed the *jugum sphenoidale*, and it separates the fossa from an air-space contained in the body of the sphenoid and named the *sphenoidal sinus* (fig. 328). Anteriorly the jugum articulates with the posterior margin of the cribriform plate; posteriorly it is limited by the anterior border of a groove, termed the *optic groove* (*sulcus chiasmatis*), which crosses the body of the sphenoid in the forepart of the middle cranial fossa and leads from one optic foramen to the other. Lateral to the jugum the floor of the fossa is formed by the *lesser wing of the sphenoid*. The posterior margin of the lesser wing, which curves medially and backwards, is free and overhangs the most anterior part of the middle cranial fossa. Laterally the lesser wing tapers to a point and meets the suture between the frontal bone and the greater

wing at or near the lateral end of the superior orbital fissure. The medial extremity of its posterior border forms a projection termed the *anterior clinoid process*. Medially the lesser wing is connected to the body of the sphenoid by two roots, separated from each other by the *optic foramen*. The anterior root, broad and flat, is continuous with the jugum sphenoidale; the posterior root, smaller and thicker, lies in the middle cranial fossa and is connected to the body of the sphenoid opposite the posterior border of the optic groove.

Fig. 324.—The internal surface of the left half of the base of the skull. (Basis cranii interna.)

Particular features.—The *crista galli* and the *frontal crest* give attachment to the falx cerebri. The *foramen cæcum* between them usually ends blindly, but on rare occasions it is patent and transmits a vein from the nasal mucosa to the superior sagittal sinus. The narrow groove on the lateral side of the crista galli is related to the gyrus rectus, and the olfactory bulb lies on the medial edge of the orbital plate of the frontal bone. The *anterior ethmoidal canal* opens on the line of the suture between the orbital plate of the frontal bone and the cribriform plate of the ethmoid (fig. 314). It is placed behind the crista galli and is difficult to identify, for it is directed medially and is overlapped above by the medial edge of the orbital plate. It transmits the anterior ethmoidal nerve and vessels, which run forward under the dura mater and gain the nasal cavity by passing downwards through a slit-like foramen at the side of the crista galli. The *posterior ethmoidal canal* opens at the posterolateral corner of the cribriform plate and is overhung by the anterior border of the sphenoid. It transmits the posterior ethmoidal vessels, but the posterior ethmoidal nerve terminates by supplying the mucous lining of the sphenoidal and posterior ethmoidal sinuses.

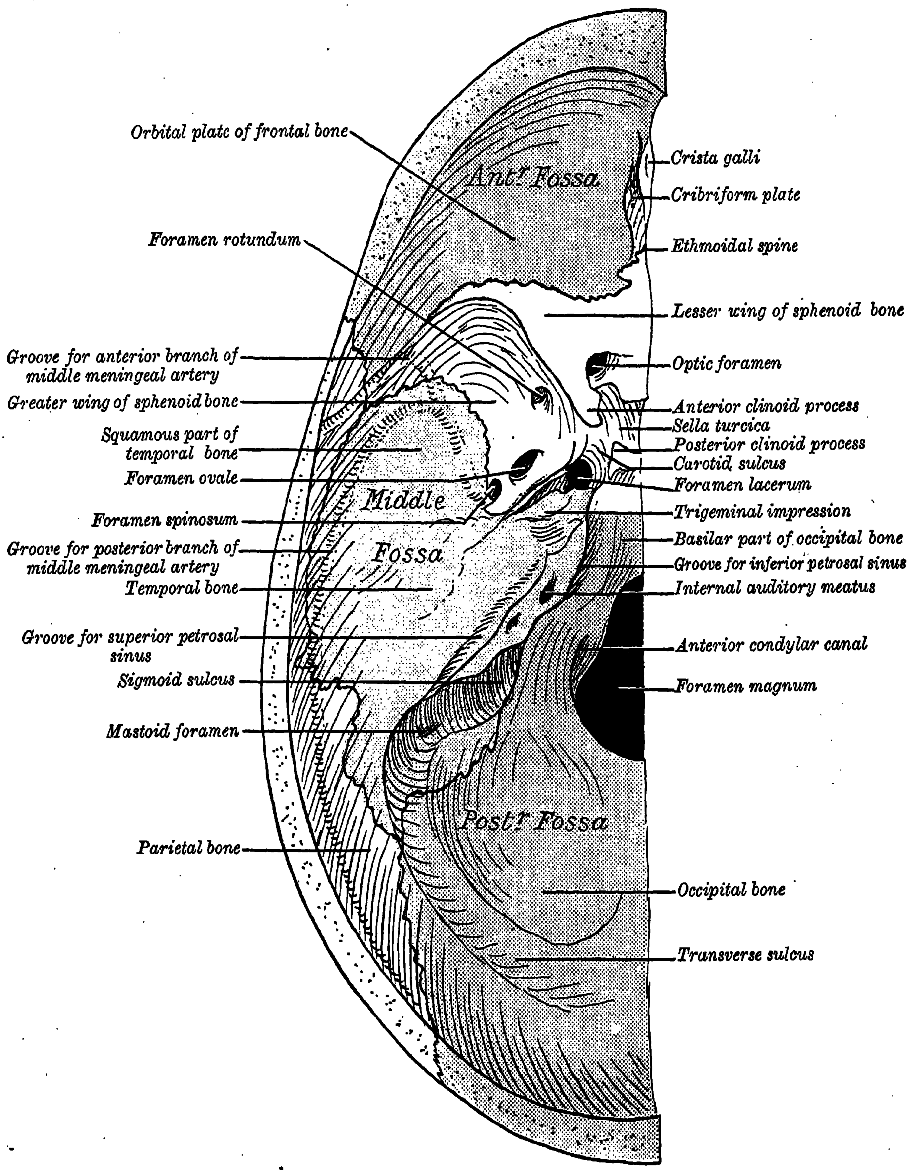
The free, posterior border of the *lesser wing* of the sphenoid fits into the stem of the lateral cerebral sulcus and may be grooved by the sphenoparietal sinus. Above, the lesser wing is related to the posterior part of the inferior surface of the frontal lobe and medially to the anterior perforated substance. Inferiorly it forms the upper boundary of the superior orbital fissure and helps to complete the roof of the orbit. The *anterior clinoid process* gives attachment to the free border of the tentorium cerebelli and is grooved on its medial aspect by the internal carotid artery as it pierces the roof of the cavernous sinus. Not infrequently the anterior clinoid process is connected to the middle clinoid process by a thin bar of bone, which completes a foramen around the internal carotid artery. The flat surface of the *jugum sphenoidale* supports the posterior ends of the gyri recti and the olfactory tracts.

The Middle Cranial Fossa (figs. 324, 325)

The **middle cranial fossa** is deeper than the anterior; it is more extensive on each side than in the median plane, and its walls bear some resemblance to a butterfly with outspread wings. In front it is bounded by the posterior borders of the

lesser wings, the anterior clinoid processes and the anterior margin of the optic groove; behind by the superior borders of the petrous parts of the temporal bones and the dorsum sellæ of the sphenoid bone; laterally by the temporal squamæ, the anterior inferior angles of the parietal bones and the greater wings of the sphenoid.

Fig. 325.—Key to fig. 324.



In the median area the floor is formed by the body of the sphenoid. In front, the *optic groove* (sulcus chiasmatis) leads on each side into the optic foramen. The sulcus does not lodge the optic chiasma, which lies above and behind it. The **optic foramen** is placed between the two roots of the lesser wing and is bounded medially by the body of the sphenoid. It is directed forwards, laterally and somewhat downwards and transmits the optic nerve and the ophthalmic artery. Immediately behind the groove the upper surface of the body of the sphenoid is shaped like a Turkish saddle and is termed the *sella turcica*. Its anterior slope is marked by a median elevation, termed the *tuberculum sellæ*, and behind that

the surface is hollowed out to form the *hypophyseal fossa* (fig. 328), which lodges the hypophysis cerebri—an important ductless gland. The floor of the hypophyseal fossa forms part of the roof of the sphenoidal sinus. (Pl. I, fig. 1.) Posterior to the fossa a plate of bone projects upwards and forwards to form the *dorsum sellæ.* On each side the superolateral angle of the dorsum sellæ is expanded to form the *posterior clinoid process.* Lateral to the sella turcica the body of the sphenoid presents a shallow *groove for the internal carotid artery*, as it runs forwards from the foramen lacerum. A small elevation marks the anterior part of the medial edge of the carotid groove and is termed the *middle clinoid process*; it may be joined to the anterior clinoid process by a thin bar of bone. Posteriorly the lateral edge of the carotid groove may be deepened by a small projection termed the *lingula.*

The **lateral part of the middle cranial fossa** is deep and its floor supports the temporal lobe of the brain. It is formed in front by the cerebral surface of the greater wing of the sphenoid and behind by the anterior surface of the petrous part of the temporal bone, while the cerebral surface of the temporal squama occupies the interval between these two bones in the lateral portion of the floor. It is related in front to the posterior part of the orbit: laterally, to the temporal fossa; and below, to the infratemporal fossa.

Anteriorly it communicates with the orbit through the **superior orbital fissure**, which is placed obliquely and is bounded above by the lesser wing, below by the greater wing, and medially by the side of the body of the sphenoid. The fissure is wider at its medial end than at its lateral end and its long axis is directed upwards, laterally and forwards. It transmits the terminal branches of the ophthalmic nerve, the ophthalmic veins, the oculomotor, trochlear and abducent nerves, and some smaller vessels.

The **foramen rotundum** pierces the greater wing of the sphenoid immediately below and a little behind the medial end of the superior orbital fissure. It leads forwards into the pterygopalatine fossa, to which it conducts the maxillary nerve.

The **foramen ovale** pierces the greater wing of the sphenoid posterior to the foramen rotundum and lateral to the lingula and the posterior end of the carotid groove. It leads downwards into the infratemporal fossa and transmits the mandibular nerve to that region.

The **foramen spinosum** lies close to the posterolateral margin of the foramen ovale, and transmits the middle meningeal artery from the infratemporal fossa to the middle cranial fossa. The artery, with its accompanying veins, runs laterally to gain the temporal squama on which it runs upwards, forwards and laterally. Crossing the temporosphenoidal suture for a second time it ascends on the greater wing and divides into anterior and posterior branches. The anterior branch proceeds upwards across the cerebral surface of the pterion and gains the anterior part of the parietal bone. In the region of the pterion the artery is often enclosed in a bony canal. The posterior branch runs backwards and upwards on to the upper part of the temporal squama and crosses the parietosquamosal suture to gain the posterior part of the parietal bone. These arteries and their branches produce conspicuous grooves in the floor and lateral wall of the middle cranial fossa.

At the posterior end of the carotid groove and posteromedial to the foramen ovale the **foramen lacerum** is situated. It is bounded behind by the apex of the petrous temporal and in front by the body of the sphenoid and the posterior border of its greater wing. This end of the foramen lacerum transmits the internal carotid artery and its accompanying nervous and venous plexuses, together with some smaller structures.

Behind the foramen lacerum the anterior surface of the petrous temporal presents a shallow depression adjoining the apex of the bone. It is occupied by the trigeminal (semilunar) ganglion, and is named the *trigeminal impression.* The ganglion lies in a special recess of the dura mater and extends forwards above the lateral part of the foramen lacerum. Posterolateral to the trigeminal impression the surface presents a shallow hollow, limited posteriorly by a transversely rounded elevation, termed the *arcuate eminence.* This elevation is produced by the superior semicircular canal, which is closely related to the floor of the middle cranial fossa in this situation.

Lateral to the trigeminal impression the anterior surface of the petrous temporal presents a narrow groove which is directed backwards and laterally and soon disappears into the *hiatus for the greater superficial petrosal nerve.* Anterolateral to the

arcuate eminence the anterior surface of the petrous temporal is formed by the **tegmen tympani**, a thin lamella of bone which forms the roof of the tympanic cavity, and extends forwards and medially above the pharyngotympanic (auditory) tube. Lateral to the arcuate eminence the posterior part of the tegmen tympani forms the roof of the tympanic antrum—an air-space in the bone which communicates in front with the tympanic cavity.

The *superior border of the petrous temporal* separates the middle cranial fossa from the posterior cranial fossa. Behind the trigeminal impression it is grooved by the superior petrosal sinus, which connects the posterior end of the cavernous sinus to the upper end of the sigmoid sinus.

Particular features.—The optic nerve carries with it through the **optic foramen** a sheath derived from the membranes of the brain. The ophthalmic artery lies below the nerve, and in contact with the posterior root of the lesser wing.

On each side of the body of the sphenoid the cavernous sinus extends from the medial end of the superior orbital fissure to the apex of the petrous part of the temporal bone. In addition to the internal carotid artery and its plexus of sympathetic nerves the sinus contains the oculomotor, the trochlear, abducent and ophthalmic nerves, but these structures do not come into contact with the bone. An anterior intercavernous sinus, which crosses the *tuberculum sellæ*, and a posterior intercavernous sinus, which crosses the front of the *dorsum sellæ*, connect the two cavernous sinuses to each other. An additional connexion is established by an irregularly loculated sinus which intervenes between the hypophysis cerebri and the floor of its fossa. The diaphragma sellæ, which surrounds the infundibulum, is connected to the tuberculum in front and to the dorsum sellæ behind. The *posterior clinoid process* gives attachment to the anterior extremity of the attached margin of the tentorium cerebelli and to the petrosphenoid ligament (p. 1057).

The **superior orbital fissure** (fig. 312) opens into the orbit between its roof and its lateral wall. Its lower border is marked by a small projection which gives attachment to the lateral part of the annulus tendinis communis. Lateral to this projection the fissure is narrow, and transmits the lacrimal, frontal and trochlear nerves, and, in addition, a small orbital branch from the middle meningeal artery and a meningeal branch from the lacrimal artery. The wider, medial end of the fissure transmits the upper and lower divisions of the oculomotor, the nasociliary—which usually lies between them—and the abducent nerve—which usually lies below them—and the ophthalmic veins. The veins pass directly into the anterior end of the cavernous sinus. At the lateral extremity of the fissure the greater wing and the orbital plate of the frontal bone articulate with each other.

The **foramen rotundum**, like the medial end of the superior orbital fissure, is intimately related to the lateral wall of the sphenoidal sinus. Originally a part of the fissure, it becomes separated secondarily. A small foramen may be present at the root of the greater wing medial to the foramen ovale; it transmits an emissary vein from the cavernous sinus and is termed the *emissary sphenoidal foramen*. In addition to the mandibular nerve the **foramen ovale** transmits the accessory meningeal artery, and, sometimes, the lesser superficial petrosal nerve. In addition to the middle meningeal artery the **foramen spinosum** transmits the nervus spinosus. Both these foramina are represented at first by notches on the margin of the greater wing, which subsequently become converted into foramina.

The **foramen lacerum**, as described above (p. 261), is a short bony canal, traversed in its whole extent only by minute meningeal branches from the ascending pharyngeal artery and a few small veins and meningeal lymphatic vessels. The internal carotid artery pierces its posterior wall (p. 261) and ascends through its upper opening. The greater superficial petrosal nerve emerges from its hiatus and runs forwards in the groove which marks the anterior surface of the petrous part of the temporal bone. It turns downwards through the foramen lacerum on the lateral side of the internal carotid artery and is joined by the deep petrosal nerve to form the nerve of the pterygoid canal. This nerve leaves the foramen lacerum above its lower opening by traversing the *pterygoid canal*, which opens on its anterior wall. The lesser superficial petrosal nerve lies to the lateral side of the greater as it emerges on the anterior surface of the petrous part of the temporal bone and may occupy a small groove.

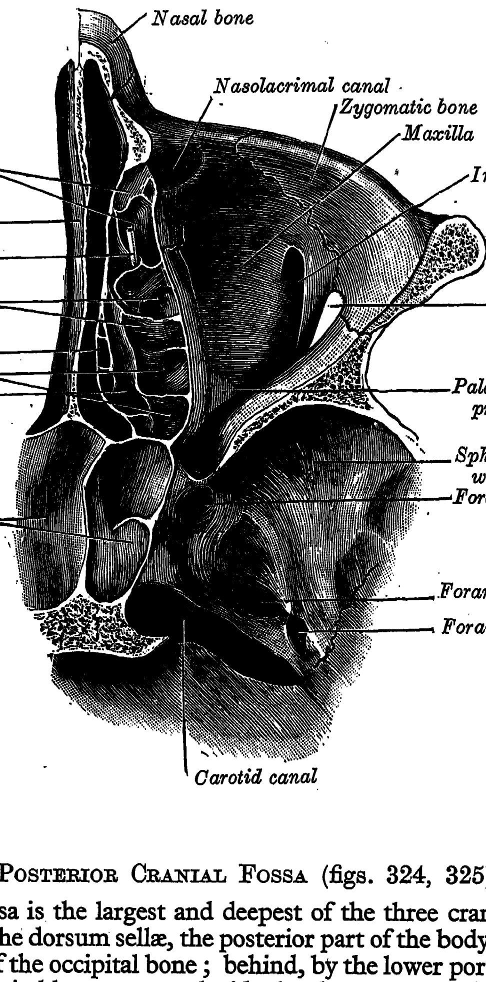
In a young skull the suture between the petrous and the squamous parts of the temporal bone may be visible at the lateral limit of the **tegmen tympani**, but it is usually obliterated in the adult skull. In this situation anteriorly, the lateral margin of the tegmen tympani turns downwards, forming the lateral wall of the bony part of the pharyngotympanic (auditory) tube, and its lower border may be visible in the floor of the squamotympanic fissure (p. 262).

Lateral to the anterior part of the tegmen tympani the part of the temporal squama which helps to form the floor of the middle cranial fossa is thin and translucent over a small area. This corresponds to the deepest part of the articular fossa on the external surface of the base of the skull.

In front of the commencement of the groove for the superior petrosal sinus the *upper*

border of the petrous temporal shows a shallow smooth notch, termed the *trigeminal notch*, which leads into the *trigeminal impression*. In this situation the roots of the trigeminal nerve intervene between the superior petrosal sinus and the bone. A tiny spicule, directed forwards and medially, marks the anterior extremity of the notch and gives attachment to the lower end of the petrosphenoidal ligament. The abducent nerve bends forwards sharply across the upper border of the temporal bone immediately in front of this bony spicule,* and so lies between the petrosphenoidal ligament and the side of the dorsum sellæ.

FIG. 326.—A horizontal section through the nasal and orbital cavities. Superior aspect.



THE POSTERIOR CRANIAL FOSSA (figs. 324, 325)

The posterior fossa is the largest and deepest of the three cranial fossæ. It is bounded in front by the dorsum sellæ, the posterior part of the body of the sphenoid and the basilar part of the occipital bone; behind, by the lower portion of the squamous part of the occipital bone; on each side, by the petrous and mastoid parts of the temporal bone, the condylar (lateral) part of the occipital bone and, above and behind, by a small part of the posterior inferior angle of the parietal bone. It contains the cerebellum behind and the pons and medulla oblongata in front.

The **foramen magnum** (p. 262) is in the floor of the fossa and is surrounded by the parts of the occipital bone. Its circumference is formed by the basilar part in front, by the condylar (lateral) part on each side and by a small portion of the squamous part behind. Just in front of its transverse diameter it is encroached on by the irregular, medial aspects of the occipital condyles, so that it is somewhat ovoid in shape and is wider behind than in front. Its narrower, anterior part lies above the odontoid process (dens) of the axis vertebra; its wider posterior part communicates below with the vertebral canal, and through it the medulla oblongata passes down to become continuous with the spinal cord.

* E. Wolff, *Journal of Anatomy*, vol. lxiii., p. 150.

In front of the foramen magnum the basilar part of the occipital bone, the posterior part of the body of the sphenoid bone and the dorsum sellæ form a sloping surface, gently concave from side to side, to support the medulla oblongata below and the pons above. On each side this area is separated from the petrous part of the temporal bone by the petro-occipital fissure, which is occupied in the recent state by a thin plate of cartilage. The fissure is limited behind by the jugular foramen, and its margins are grooved by the inferior petrosal sinus.

The **jugular foramen** (p. 262) lies at the posterior end of the petro-occipital suture, and leads forwards, downwards and laterally to the external surface of the base. Its upper border is sharp and irregular and presents a *notch for the glossopharyngeal nerve*. Its lower border is smooth and regular. The posterior part of the foramen transmits the sigmoid sinus, which is continuous below with the internal jugular vein. In front of the vein the accessory, vagus and glossopharnygeal nerves, in that order from behind forwards, traverse the foramen to gain the upper part of the neck. The most anterior part of the foramen transmits the inferior petrosal sinus.

Medial to the lower border of the jugular foramen a rounded elevation, termed the *jugular tubercle*, marks the condylar part of the occipital bone. It lies above and somewhat in front of the inner opening of the **anterior condylar (hypoglossal) canal**, which pierces the bone at the junction of the basilar with the condylar part and transmits the hypoglossal nerve.

The posterior surface of the petrous part of the temporal bone forms a large portion of the lateral (or anterolateral) wall of the posterior fossa. Above the anterior part of the jugular foramen the **internal auditory meatus** (fig. 325) runs transversely in a lateral direction. It is a short passage, about 1 cm. long, closed laterally by a perforated plate of bone which separates it from the internal ear. It transmits the facial and auditory nerves.

Behind the petrous temporal the lateral wall of the posterior cranial fossa is formed by the mastoid part of the temporal bone. Anteriorly it is marked by a wide groove, which runs forwards and downwards, then downwards and medially, and finally forwards to the posterior limit of the jugular foramen. This groove contains the sigmoid sinus and is termed the **sigmoid sulcus** (fig. 325). At its upper end, where it touches the postero-inferior angle of the parietal bone, the groove is continuous with that for the transverse sinus and crosses the parietomastoid suture. As it descends, it lies behind the tympanic antrum and forms a very important relation of that cavity. In this part of its course the *mastoid foramen* opens near its posterior margin and transmits an emissary vein from the sinus. In its lowest part the sigmoid sulcus crosses the occipitomastoid suture and grooves the jugular process of the occipital bone. It is usually deeper on the right than on the left side.

Behind the foramen magnum the squamous part of the occipital bone is marked in or near the median plane by the *internal occipital crest*, which ends above and behind in an irregular elevation named the *internal occipital protuberance*. On each side of the protuberance a wide shallow groove curves laterally with a slight upward convexity to the postero-inferior angle of the parietal bone. It is produced by the transverse sinus, is usually deeper on the right side, and at its lateral extremity is continuous with the groove for the sigmoid sinus. Below the groove for the transverse sinus the internal occipital crest divides the bone into two gently hollowed fossæ, which lodge the cerebellar hemispheres.

When the *posterior condylar canal* is present (fig. 343), its inner orifice usually lies behind and lateral to the orifice of the anterior condylar (hypoglossal) canal, but it may lie nearer to the jugular foramen. It transmits an emissary vein from the lower end of the sigmoid sinus.

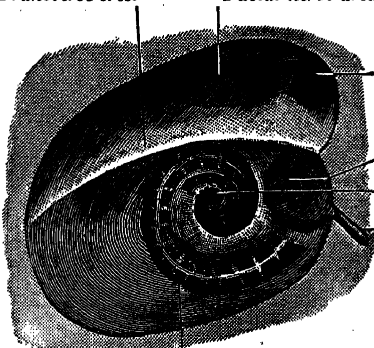
Particular features.—The anterior wall of the fossa is related to the network of basilar sinuses which connects the two inferior petrosal sinuses and communicates below with the internal vertebral venous plexus. A little in front of the foramen magnum the membrana tectoria is attached to the basilar part of the occipital bone (fig. 513), covering the attachment of the apical ligament of the odontoid process. The *jugular tubercle* is often grooved by the glossopharyngeal, vagus and accessory nerves, as they pass to the jugular foramen. In addition to the hypoglossal nerve the **anterior condylar canal** transmits a meningeal branch of the ascending pharyngeal artery. The canal is often subdivided into two parts by a small bar of bone, and this may be related to the composite origin of the hypoglossal

nerve (p. 1031). The roughened medial aspect of the *occipital condyle* (fig. 342) gives attachment to the alar ligament.

The lower and posterior borders of the **jugular foramen** (pp. 262, 263, and 271) are smooth and regular, but its upper border is sharp and interrupted by a notch, the ends of which may succeed in dividing the foramen into two or sometimes three compartments. The notch lodges the inferior (petrous) ganglion of the glossopharyngeal nerve and at its deepest part is pierced by the *cochlear canaliculus,* which contains the aqueduct of the cochlea.

The **internal auditory meatus** transmits the auditory nerve, both the motor and the sensory roots of the facial nerve and the internal auditory vessels. It is about 1 cm. in length and its *fundus* is separated from the internal ear by a vertical plate which is divided into two unequal portions by a *transverse crest* (fig. 327). Above the crest anteriorly the bone is pierced by the **facial canal,** which conducts the facial nerve through the petrous temporal to the stylo-mastoid foramen. Behind the opening of the facial canal there is a small depression, termed the *superior vestibular area,* which presents a number of small openings for the passage of the nerves to the utricle and the superior and lateral semi-

Fig. 327.—A diagrammatic view of the lateral end of the right internal auditory meatus. (Testut.)



circular ducts. Below the transverse crest anteriorly lies the *cochlear area,* in which a number of small, spirally arranged openings encircle the central canal of the cochlea and constitute the *tractus spiralis foraminosus.* Behind the cochlear area the *inferior vestibular area* presents several openings for the nerves to the saccule. Below and behind the inferior vestibular area the *foramen singulare* gives passage to the nerve to the posterior semicircular duct.

Behind the orifice of the internal auditory meatus a thin plate of bone with an irregularly curved margin projects backwards, and the slit which it bounds contains the external opening of the *aqueduct of the vestibule* (fig. 350). Within the aqueduct the saccus and ductus endolymphaticus are contained together with a small artery and vein. In the area between the internal auditory meatus and the external opening of the aqueduct of the vestibule there is a small depressed area, termed the *subarcuate fossa,* which lodges a small process of the dura mater. It lies nearer to the upper border of the bone (fig. 350) and is pierced by a small vein. In the infant the fossa is relatively large and extends as a short blind tunnel under the superior semicircular canal; it corresponds to the floccular fossa in some animals.

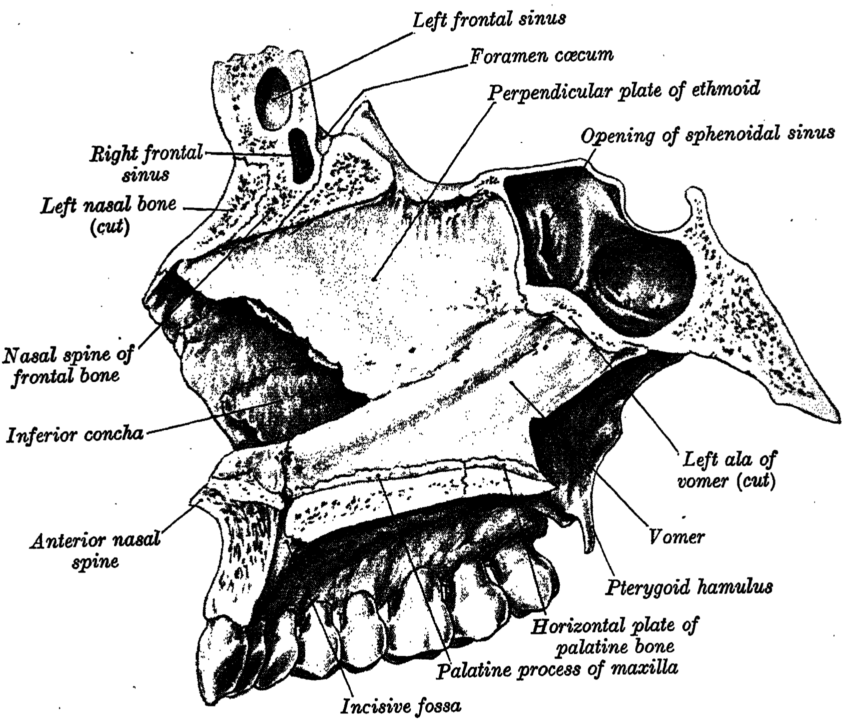
In addition to an emissary vein, the *mastoid foramen* transmits a meningeal branch of the occipital artery, which is sometimes large enough to produce a groove on the squamous part of the occipital bone.

The *internal occipital crest* gives attachment to the falx cerebelli and may be grooved by the occipital sinus, which is sometimes duplicated and is occasionally a large vessel. Its lower end is related to the inferior vermis of the cerebellum. The *internal occipital protuberance* is related to the confluence of sinuses and is grooved on each side by the commencement of the transverse sinus. The margins of the *groove for the transverse sinus* give attachment to the two layers of the tentorium cerebelli. Traced in a lateral direction, the groove reaches the lowest part of the posterior inferior angle of the parietal bone, where it becomes continuous with the groove for the sigmoid sinus (p. 271). On each side of the internal occipital crest the bone is thin and translucent, in marked contrast to the regions of the crest and of the internal occipital protuberance.

THE NASAL CAVITY

The **nasal cavity** is the first of the respiratory passages and is an irregularly shaped space which extends from the roof of the mouth upwards to the base of the skull. It is subdivided into right and left halves by a *septum* (fig. 328), which is approximately median in position. In the dried skull the septum is deficient anteriorly, and as a result a single *anterior nasal aperture* is present on the norma frontalis. The septum, however, reaches the posterior limit of the cavity, which communicates with the nasal part of the pharynx through a pair of *posterior nasal apertures*, placed immediately above the posterior border of the bony plate. The cavity is wider below than above and is widest and deepest in its central part. It communicates with the frontal, ethmoidal, maxillary and sphenoidal sinuses.

FIG. 328.—The nasal septum. Left side.



Each half of the nasal cavity has a roof, a floor, a lateral and a medial wall—the medial wall being formed by the corresponding side of the nasal septum.

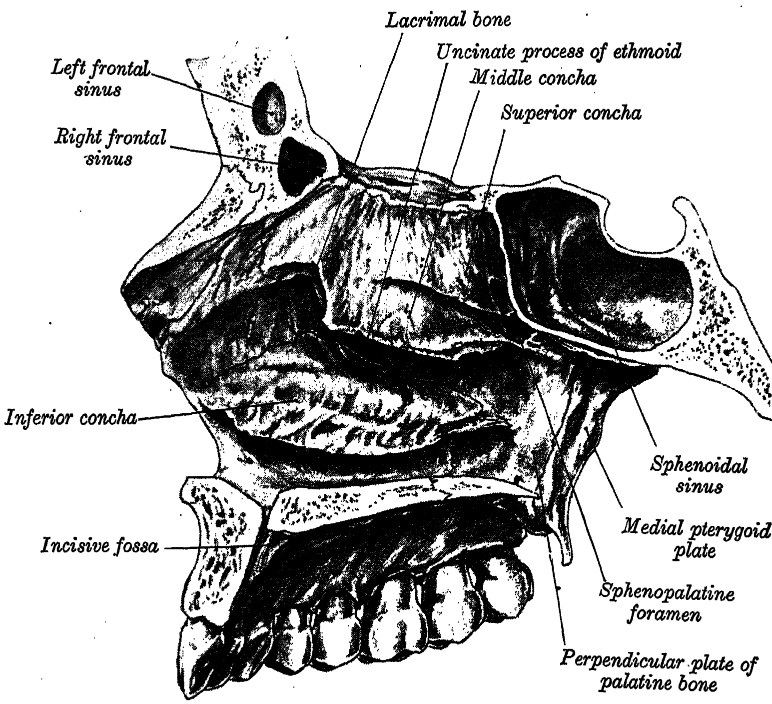
The **roof** (figs. 329, 330) is horizontal in its middle part but slopes downwards in front and behind. The anterior sloping part is formed by the frontal and nasal bones and contributes to the formation of the external nose. The horizontal part is formed by the cribriform plate of the ethmoid bone and separates the nasal cavity from the median part of the floor of the anterior cranial fossa. It presents numerous small openings for the passage of the olfactory nerves. The posterior sloping part is formed by the body of the sphenoid and is interrupted by the rounded orifice of the sphenoidal sinus.

The **floor** is smooth, gently concave from side to side, and slopes upwards a little as it passes backwards from the anterior aperture to the posterior aperture. It is formed by the upper surface of the bony plate and therefore intervenes between the nasal and oral cavities. Portions of four bones contribute to its formation. Anteriorly the palatine processes of the two maxillæ meet in the median plane, and behind them the horizontal plates of the palatine bones articulate with each other in the median plane and with the palatine processes of the maxillæ in front. In

its anterior part the floor close to the septum presents a small funnel-shaped opening which leads into the *incisive canal.*

The **medial wall** is formed by the *bony septum* (fig. 328), which extends between the roof and the floor. It is a thin sheet of bone and presents a wide deficiency in front, occupied in the recent state by the septal cartilage. It is formed almost entirely by the vomer and the perpendicular plate of the ethmoid. The *vomer* extends from the under surface of the body of the sphenoid to the bony palate and forms the lower and posterior part of the septum, including its free, posterior border. It is marked by small furrows for vessels and nerves. The *perpendicular plate of the ethmoid* forms the upper and anterior part of the septum (fig. 328) and is continuous above with the cribriform plate (p. 265). The septum is often deflected to one or other side, and the deviation occurs most commonly on the line of the vomero-ethmoidal suture.

FIG. 329.—The roof, floor and right lateral wall of the nasal cavity. Drawn from the same skull as fig. 328.



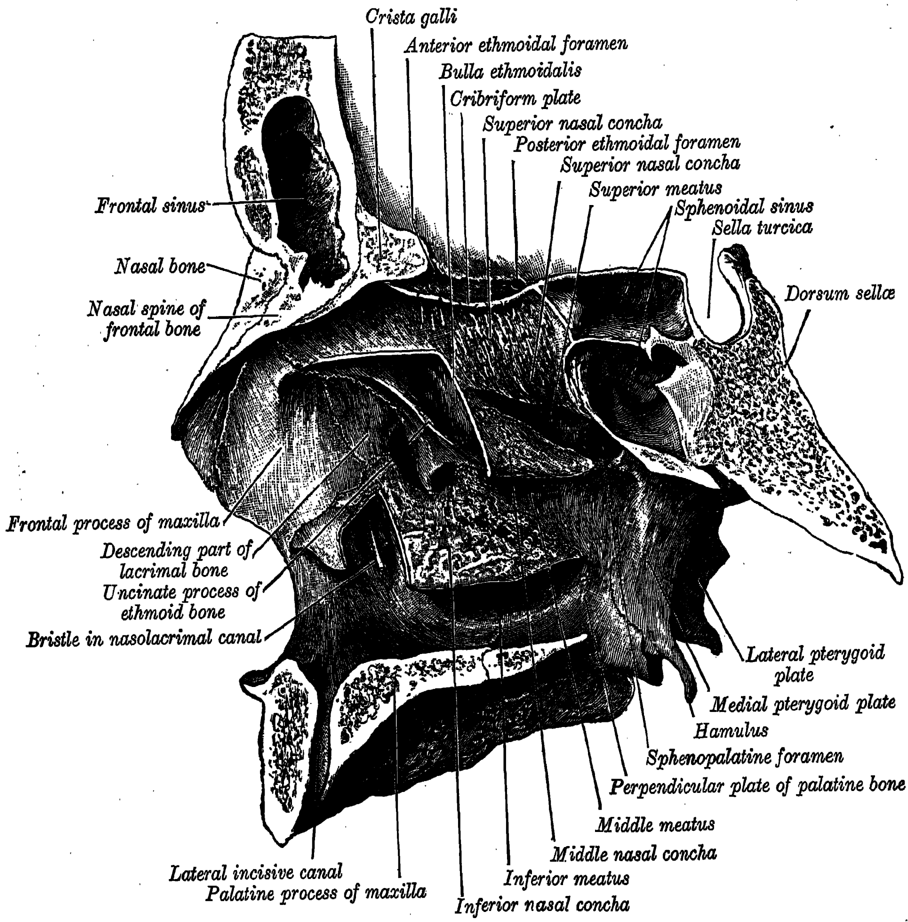
The **lateral wall** (figs. 329, 330) is very irregular owing to the presence of three bony projections termed the inferior, middle and superior nasal conchæ. It is formed, for the most part, by the nasal surface of the maxilla below and in front, by the perpendicular plate of the palatine bone posteriorly, and above by the nasal surface of the ethmoidal labyrinth, which intervenes between the nasal cavity and the orbit. The three conchæ project downwards and slightly medially, and each forms the roof of a passage which communicates freely with the nasal cavity. These passages are termed the meatuses of the nose.

The *inferior concha* is a curved lamina of thin bone and is an independent entity. It articulates with the nasal surface of the maxilla and the perpendicular plate of the palatine bone, and possesses a free lower border, which is gently curved. The *inferior meatus* lies under cover of the inferior concha and extends downwards to the floor of the nasal cavity. It is the largest of the three meatuses and extends almost the entire length of the lateral wall of the nose. The inferior meatus is deepest at the junction of its anterior and middle thirds, and in this situation it presents the lower orifice of the nasolacrimal canal.

The *middle* and *superior conchæ* are projections from the medial surface of the ethmoidal labyrinth. The *middle concha* is much the larger and extends backwards

to articulate with the perpendicular plate of the palatine bone. The *middle meatus* is placed between the middle and inferior conchæ. Its lateral wall displays several important features which can be examined only after the removal of the middle concha (fig. 330). Its upper part is occupied by a rounded elevation, termed the *ethmoidal bulla*, which contains the middle ethmoidal sinuses. Below and in front of the bulla a curved fissure passes downwards and backwards across the lateral wall of the meatus. It is named the *hiatus semilunaris*, and its upper or anterior end is continuous with a curved canal, termed the *infundibulum*. In its posterior part the

FIG. 330.—The lateral wall of the right nasal cavity, with parts of the middle and inferior nasal conchæ removed.



floor of the hiatus semilunaris receives the opening of the maxillary sinus, which is usually hidden by the edge of the fissure. The anterior ethmoidal sinuses open into the infundibulum, which, in fifty per cent. of skulls, opens above into the frontal sinus. It may, however, be closed above by the fusion of the bulla ethmoidalis with the edge of the hiatus semilunaris and, in that event, the frontal sinus opens independently into the anterior part of the middle meatus. The middle ethmoidal sinuses open above, or near, the bulla. The lateral wall of the meatus below the hiatus semilunaris may be partially deficient, and the gap or gaps lead into the maxillary sinus. In the recent state they are usually closed by the nasal mucosa.

The *superior concha* is a small curved lamina which lies above and behind the middle concha. It roofs in the *superior meatus*, which is much the shortest and shallowest of the three meatuses; it receives the opening of the posterior ethmoidal sinuses. Immediately behind the superior meatus the sphenopalatine foramen,

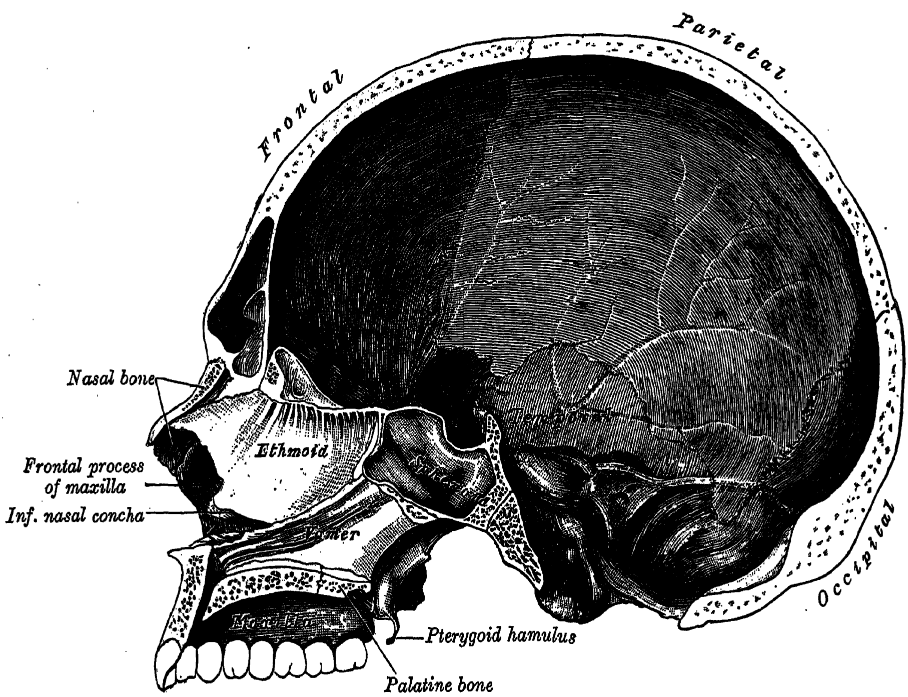
which opens into the pterygopalatine fossa, pierces the lateral wall of the nasal cavity. A narrow interval, termed the *spheno-ethmoidal recess*, separates the superior concha from the anterior surface of the body of the sphenoid, through which the sphenoidal sinus opens into the nasal cavity.

The **anterior nasal aperture** has been described on p. 246.

The **posterior nasal apertures (choanæ)** are separated from each other by the posterior border of the vomer. They are bounded below by the posterior border of the horizontal plate of the palatine bone, above by the base of the skull; and laterally, on each side, by the medial pterygoid plate.

Particular features.—The anterior sloping part of the **roof** (fig. 329) is formed by the nasal bone and the nasal spine of the frontal bone. In addition to the numerous small foramina for the transmission of the olfactory nerves, the horizontal part of the roof

FIG. 331.—A sagittal section through the skull.



presents a separate foramen, situated anteriorly, which gives passage to the anterior ethmoidal nerve and vessels. The posterior sloping part of the roof is formed above by the anterior aspect of the body of the sphenoid, with which the sphenoidal concha (p. 293) is fused, and below by the ala of the vomer and the sphenoidal process of the palatine bone.

The **floor** (fig. 328) is crossed at the junction of its middle and posterior thirds by the palatomaxillary suture. Close to the median plane anteriorly it is pierced by the incisive canal, which transmits the terminal part of the long sphenopalatine (nasopalatine) nerve and the greater palatine vessels. Both incisive canals open into the incisive fossa on the bony palate and they traverse the line of union of the os incisivum (premaxilla) with the maxilla; they represent a primitive communication between the mouth and the nose.

At the upper and lower borders of the **medial wall** (fig. 328) other bones, in addition to the vomer and the perpendicular plate of the ethmoid, make minor contributions to the septum. Above and in front, the nasal bones and the frontal spine, above and behind, the rostrum and crest of the sphenoid, and below, the nasal crests of the maxillæ and palatine bones all take small parts in its constitution. The vomer is grooved by the long sphenopalatine nerve, as it runs downwards and forwards to reach the incisive canal.

The **lateral wall** (figs. 329, 330) is formed anteriorly and above by the nasal bone and the frontal process of the maxilla. Behind the frontal process of the maxilla, and articulating with its posterior border, the lacrimal bone lies on the lateral wall of the middle meatus and articulates below with the lacrimal process of the inferior concha. These two bones form the medial wall of the **nasolacrimal canal** (fig. 330), which conducts the nasolacrimal duct to the inferior meatus. Posteriorly the lacrimal bone articulates with the ethmoidal labyrinth and

helps to close some of the ethmoidal sinuses. The *uncinate process of the ethmoid* springs from this part of the labyrinth and curves downwards and backwards in the lateral wall of the middle meatus. It is a very thin and fragile process, about 3 mm. wide, which curves across the maxillary hiatus and articulates near its extremity with the ethmoidal process of the inferior concha. The concave, posterior border of the process is free and forms the medial edge of the hiatus semilunaris; the convex anterior border is free in its upper part only. Owing to its position relative to the maxillary hiatus the uncinate process helps to form the medial wall of the maxillary sinus. The *maxillary hiatus*, which forms such a conspicuous opening on the nasal surface of the maxilla (fig. 382), is reduced in size very considerably by the neighbouring bones. Its lower part is covered by the inferior concha and its maxillary process; above the inferior concha the uncinate process of the ethmoid, as already stated, encroaches on the gap. Posteriorly the anterior part of the perpendicular plate of the palatine bone closes it in still further, and above and in front small portions of the ethmoidal labyrinth and the lacrimal bone overlap its margins (fig. 383). As a result, the maxillary hiatus is reduced sometimes to a single orifice in the floor of the posterior part of the hiatus semilunaris, although as a rule additional openings exist behind the uncinate process, and between its lower border and the upper border of the inferior concha. The *bulla ethmoidalis* is very variable in its size and shape and, as already mentioned, may be fused with the upper part of the uncinate process. In that event the duct of the frontal sinus opens into the upper part of the middle meatus medial to the blind end of the infundibulum. A third concha is often present on the medial surface of the ethmoidal labyrinth above and behind the posterior end of the superior concha; it is little more than a slight ridge, separated from the superior concha by a shallow depression. The *sphenopalatine foramen* (fig. 329) lies at the posterior limit of the superior meatus. It transmits the sphenopalatine artery and the long and short sphenopalatine nerves from the pterygopalatine fossa. The foramen is bounded above by the body of the sphenoid and the sphenoidal concha; below by the notched upper border of the perpendicular plate of the palatine bone, and in front and behind by its orbital and sphenoidal processes respectively.

THE MANDIBLE [MANDIBULA] (figs. 332, 333)

The **mandible**, which is the largest and strongest bone of the face, has a curved, horizontal *body*, which is convex forwards, and two broad *rami*, which project upwards from the posterior ends of the body.

The **body** of the mandible is curved like a horseshoe, and possesses an external and an internal surface, separated by upper and lower borders. The *external surface* is marked in the upper part of the median plane by a faint ridge, often indistinguishable, which indicates the line of fusion of the two halves of the fœtal bone. Inferiorly the ridge divides to enclose a triangular raised area, termed the *mental protuberance*, the base of which is depressed in the centre but raised on each side to form the *mental tubercle*. Below the interval between the two premolar teeth, or below the second premolar, the *mental foramen*, which gives exit to the mental nerve and vessels, opens on the surface. A faint ridge, termed the *oblique line*, runs upwards and backwards from the mental tubercle, to become salient behind, where it is continuous with the anterior border of the ramus.

The lower border of the body is termed the *base of the mandible*. It extends backwards and laterally from the symphysis menti, and becomes continuous with the lower border of the ramus behind the third molar tooth. Near the median plane it presents a small, roughened depression, named the *digastric fossa*. Behind the digastric fossa the base is thick and rounded and presents a slight downward convexity.

The upper border of the body is formed by the *alveolar part*, which is hollowed into sixteen *sockets* (alveoli) for the roots of the teeth. These sockets vary in size and depth, and are single or subdivided by septa according to the teeth which they contain.

The *internal surface* is divided into two areas by an oblique ridge termed the **mylohyoid line.** Sharp and distinct in the region of the molar teeth, it becomes almost undiscernible in front. It commences behind the third molar tooth, not quite 1 cm. from the upper border of the bone, and runs forwards and downwards to reach the symphysis menti in the interval between the two digastric fossæ. Below the mylohyoid line the surface is slightly hollowed out and forms the *submandibular fossa* for the lodgment of the submandibular (submaxillary) salivary gland. The area above the mylohyoid line widens as it is traced forwards and presents in front a triangular area, termed the *sublingual fossa*, which lodges the sublingual gland. Above the sublingual fossa and extending backwards to the third

FIG. 332.—The left half of the mandible. Lateral aspect.

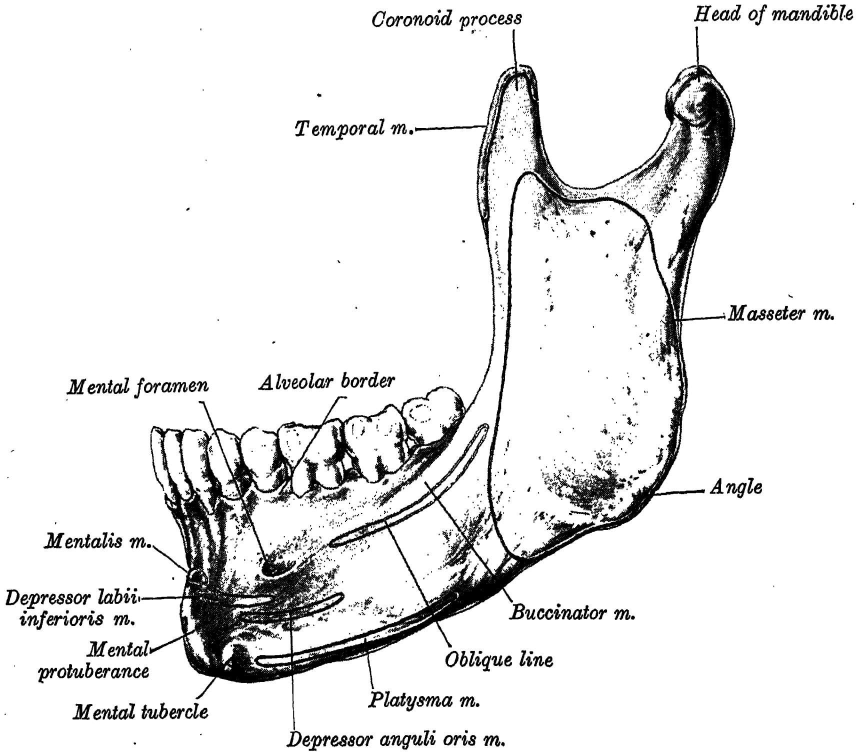
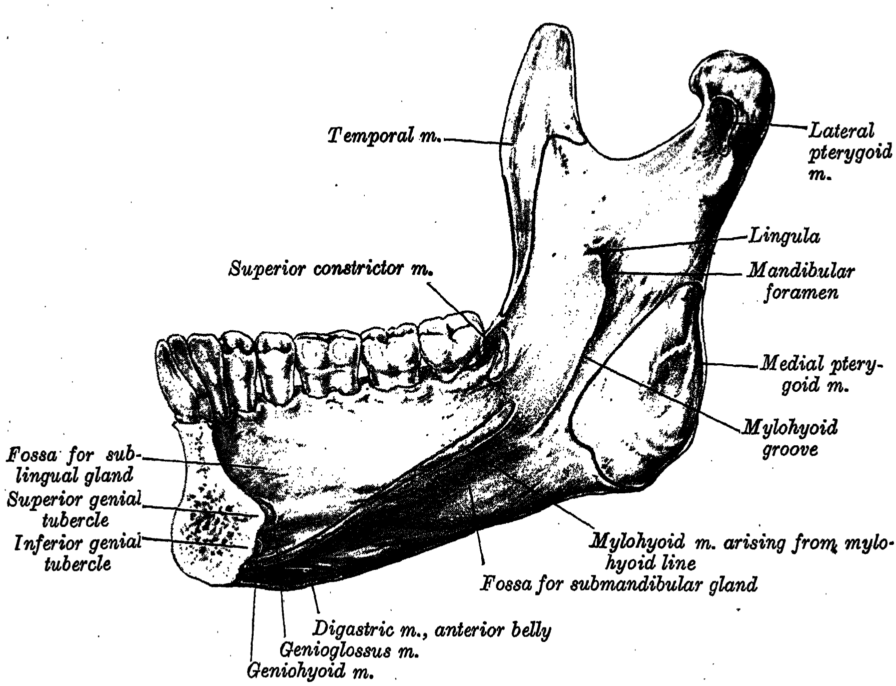


FIG. 333.—The right half of the mandible. Medial aspect.



molar tooth a strip of the bone is closely covered with the mucous membrane of the mouth. Above the anterior ends of the mylohyoid lines the posterior surface of the symphysis menti is marked by a small irregular elevation, which may be divisible into two or more parts, termed the *genial tubercles* (mental spine). Posteriorly, a groove, termed the *mylohyoid groove*, extends downwards and forwards on to the body from the ramus and passes below the posterior end of the mylohyoid line.

The **ramus** (figs. 332, 333) of the mandible is quadrilateral in shape, and presents two surfaces, four borders and two prominent processes. The *lateral surface* is flat and marked by oblique ridges in its lower part. The *medial surface* presents, a little above its centre, an irregular opening, named the *mandibular foramen.* This opening leads into the *mandibular canal*, which curves downwards and forwards to open on the external surface of the body at the mental foramen. It transmits the nerve and vessels which supply the teeth of the mandible. In front and on the medial side the foramen is obscured by a thin triangular process termed the *lingula.* The *mylohyoid groove* commences behind the lingula and runs downwards and forwards to reach the internal surface of the body. The part of the medial surface which lies behind the groove is marked by a number of short rough ridges. The *inferior border* of the ramus is continuous in front with the base of the mandible; behind, it meets the posterior border at the **angle of the mandible.** When the angle is prominent the inferior border presents a concavity, directed downwards. Eversion of the angle is characteristic of the male mandible; in the female it is frequently inverted. The *upper border* is thin and bounds a wide notch, termed the *mandibular notch.* It is surmounted in front by a triangular, flattened projection, termed the coronoid process, and behind by a stout, articular process named the condyloid process. The *posterior border*, thick and rounded, extends from the back of the condyloid process to the angle of the mandible. It is gently curved, being convex backwards above and concave below, and is intimately related to the parotid gland. The *anterior border* is thin above, where it is continuous with the anterior border of the coronoid process, and thicker below, where it is continuous with the oblique line.

The **coronoid process** is a flattened triangular projection, directed upwards and slightly forwards. Its posterior border bounds the mandibular notch and its anterior border is continuous with the anterior border of the ramus. Its margins and medial surface provide insertion for most of the fibres of the temporalis muscle. The **condyloid process** is expanded above to form the *head* of the mandible, which is covered with fibrocartilage. It articulates with the articular fossa of the temporal bone—an articular disc intervening. It is convex in all directions and its transverse measurement is greater than its anteroposterior. The lateral aspect of the head forms a blunt point which projects beyond the lateral surface of the rest of the ramus and can be felt in the living subject just in front of the tragus of the auricle. When the mouth is opened the head passes downwards and forwards, and the examining finger sinks into a small depression. The constricted portion below the head is termed the *neck of the mandible.* It is slightly flattened from before backwards, and its anterior aspect is limited on the lateral side by the backward continuation of the margin of the mandibular notch. Medial to this ridge the anterior surface of the neck presents a rough muscular impression.

The **mandibular canal** runs from the mandibular foramen obliquely downwards and forwards in the ramus, and then horizontally forwards in the body below the sockets of the teeth, with which it communicates by small openings. It contains the inferior dental (alveolar) nerve and vessels, from which branches enter the roots of the teeth. Between the roots of the first and second premolars, or below the root of the second premolar tooth, the mandibular canal divides into *mental* and *incisive canals*; the mental canal runs upwards, backwards and laterally to reach the mental foramen; the incisive canal is continued forwards below the incisor teeth.

Particular features.—A small shallow fossa marks the bone below the incisor teeth and gives origin to the mentalis and a part of the orbicularis oris muscle. The anterior end of the oblique line gives origin to the depressor labii inferioris (quadratus labii inferioris) and the depressor anguli oris (triangularis) muscles. The platysma is inserted into the bone below these muscles and extends backwards beyond them. The lower margin of the **mental foramen** is sharp and the mental nerve is directed upwards and backwards as it emerges

from the bone. Adjoining the alveolar border the bone is closely covered with the mucous membrane of the mouth. Immediately below this area, in the region of the molar teeth, the buccinator muscle has a linear origin, which extends medially behind the last molar tooth to the attachment of the pterygomandibular ligament.

The **mylohyoid** line gives origin to the mylohyoid muscle. Above its posterior end the bone gives origin to fibres of the superior constrictor muscle of the pharynx, and the pterygomandibular ligament (raphe) is attached immediately behind the third molar tooth. The lingual nerve gains the tongue by passing above the posterior end of the mylohyoid line, and in this situation is closely related to the inner surface of the mandible. A strip of bone along the alveolar border is covered by the mucous membrane of the mouth, and the sublingual gland lies in contact with the bone anteriorly between this area and the mylohyoid line. The upper *genial tubercles* give origin to the genioglossi and the lower to the geniohyoid muscles; both tubercles are placed above the anterior ends of the mylohyoid lines. The *submandibular fossa* lodges some of the submandibular lymph glands in addition to the salivary gland, and the facial (external maxillary) artery may come into contact with this region as it descends to curl round the base of the mandible, where it sometimes produces a shallow groove. The *digastric fossa* gives origin to the anterior belly of the digastric and lies below the anterior end of the mylohyoid line.

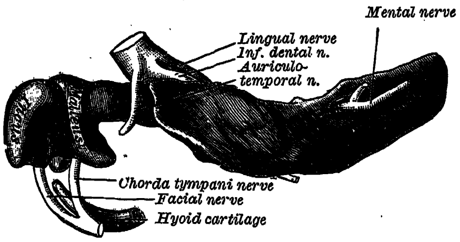


FIG. 334.—The right half of the mandible of a human embryo 24 mm. long. Lateral aspect. (From a model by Low.)

The **ramus** and its processes provide insertion for all the principal muscles of mastication. Its *lateral surface* gives insertion to the masseter muscle, except at its upper and posterior part, where it is covered by the parotid gland.

The *medial surface* gives insertion to the medial pterygoid muscle at the roughened area which lies behind and below the mylohyoid groove. The **mandibular foramen** admits the inferior dental (inferior alveolar) nerve and vessels to the mandibular canal. Its medial border is formed by the *lingula*, to which the lower end of the sphenomandibular ligament is attached. Posterior to the lingula the mylohyoid nerve and vessels enter the *mylohyoid groove*, which may be converted into a bony canal in a part of its extent. The groove reaches the body of the mandible below the posterior end of the mylohyoid line, and the nerve and vessels then pass on to the superficial aspect of the mylohyoid muscle. In front of the mylohyoid groove and below the lingula the medial surface of the ramus is related to the medial pterygoid muscle, but the lingual nerve intervenes between the muscle and the bone, as it runs downwards and forwards to reach the tongue The lowest fibres of insertion of the temporalis muscle descend beyond the coronoid process and are attached to the *anterior border* of the ramus and the adjoining part of the medial surface. The area above and behind the mandibular foramen is related to the maxillary (internal maxillary) artery and its inferior dental branch, and the part adjoining the mandibular notch is in relation with the lateral pterygoid muscle. The *mandibular notch* transmits the masseteric nerve and vessels from the infratemporal fossa.

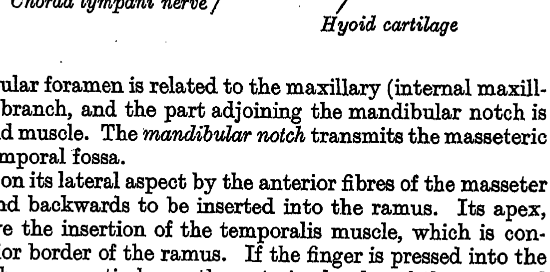


FIG. 335.—The right half of the mandible of a human embryo 24 mm. long. Medial aspect. (From a model by Low.)

The **coronoid process** is covered on its lateral aspect by the anterior fibres of the masseter muscle as they pass downwards and backwards to be inserted into the ramus. Its apex, margins and medial surface receive the insertion of the temporalis muscle, which is continued downwards along the anterior border of the ramus. If the finger is pressed into the yielding part of the cheek below the zygomatic bone, the anterior border of the coronoid process can be identified in the living subject when the mouth is opened. Owing to the way in which it is expanded, the **condyloid process** projects beyond the surfaces of the ramus, but more so on the medial than on the lateral side. The articular *head of the mandible* extends only for a short distance down the anterior surface of the process, but it covers the whole of its superior aspect and descends for 5 mm. or more on its posterior aspect. Its superior aspect slopes medially and slightly downwards and backwards. Its projecting

lateral part is separated from the cartilaginous part of the external auditory meatus by a portion of the parotid gland. The smooth lateral aspect of the *neck of the mandible* gives attachment to the temporomandibular ligament (fig. 504) and is covered by the parotid gland. The rough impression on the front of the neck receives the insertion of the lateral pterygoid muscle. The medial surface of the neck is related to the auriculotemporal nerve above and to the maxillary (internal maxillary) artery below.

The relation of the parotid gland to the mandible requires special mention. It occupies the interval below the external auditory meatus, bounded in front by the posterior border of the ramus, behind by the mastoid process and medially by the styloid process; but it extends forwards beyond this area and covers the lateral aspect of the temporomandibular joint and the part of the lateral surface of the ramus behind the masseter muscle. In addition it curls round the posterior border and comes into contact with the medial aspect of the ramus just above the insertion of the medial pterygoid muscle.

FIG. 336.—The right half of the mandible of a human embryo 95 mm. long. Lateral aspect. (The nuclei of cartilage are stippled.) (From a model by Low.)

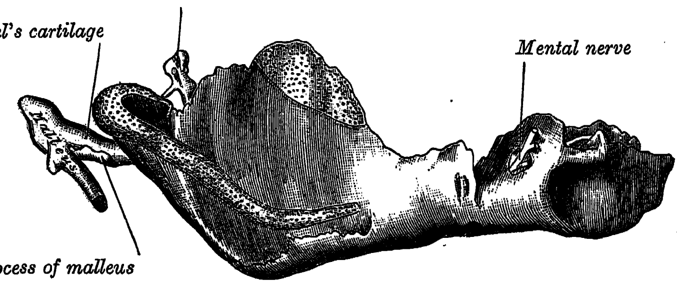
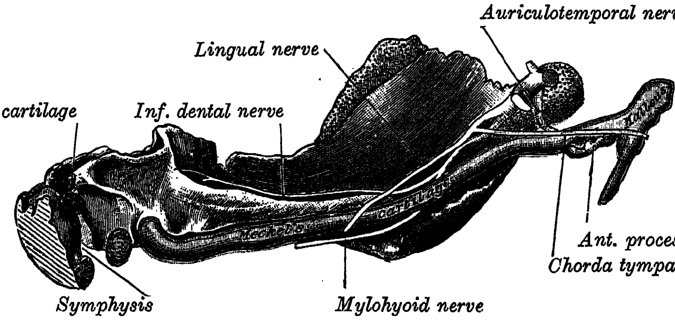


FIG. 337.—The right half of the mandible of a human embryo 95 mm. long. Medial aspect. (The nuclei of cartilage are stippled.) (From a model by Low.)



Ossification.—The mandible is ossified in the fibrous membrane covering the outer surfaces of Meckel's cartilages. This pair of cartilages form the cartilaginous bars, or skeletal elements of the mandibular arches (p. 99). Their dorsal or cranial ends are connected with the cartilaginous ear-capsules, and their ventral ends are joined to each other by mesenchymal tissue. They run forwards below the condyloid processes in the 95 mm. embryo and then, bending downwards, lie in a groove near the lower border of the bone; in front of the canine teeth they incline upwards to the symphysis menti. From the proximal end of each cartilage the malleus and incus—two of the three ossicles of the middle ear—are developed; the next succeeding portion, as far as the lingula of the mandible, disappears, but its sheath persists to form the sphenomandibular ligament. The part of the cartilage which stretches from the tooth-bud of the second milk molar to a point a little behind the anterior end of the mandible occupies, for a time, a tunnel in the bone, but is ultimately absorbed. The portion below the incisor teeth is ossified and incorporated with the mandible.

Ossification takes place in the membrane covering the outer surfaces of Meckel's cartilages (figs. 334 to 337), and each half of the bone is formed from one centre,* which appears near the mental foramen about the sixth week of fœtal life, i.e. just after the appearance of the primary centres for the clavicle (p. 340). By the tenth week the portion of Meckel's cartilage which lies below the incisor teeth is surrounded and invaded by the membrane-bone. Somewhat later, accessory pieces of cartilage make their appearance—viz. a wedge-shaped piece in the condyloid process and extending downwards through the ramus; a small patch along the anterior border of the coronoid process; and smaller nodules in the front part of both alveolar walls and along the front of the base of the bone. These accessory nodules of cartilage are invaded by the surrounding membrane-bone and undergo absorption. The inner alveolar border is formed in the human mandible by an ingrowth from the main mass of the bone.

A number of small ossicles, termed the *ossicula mentalia,* appear in the fibrous tissue of the symphysis about the seventh month of fœtal life. They enlarge and very soon fuse with one another and with the mandible in no fixed order. Usually two or four in number, they are responsible for the formation of the mental protuberance. Whether they ossify in the remains of the ventral ends of Meckel's cartilages or in the fibrous tissue of the symphysis is uncertain.

The Changes produced in the Mandible by Age

At birth (fig. 338 A, B) the body of the bone is a mere shell, enclosing the sockets of the deciduous teeth, imperfectly partitioned off from one another. The mandibular canal runs near the lower border of the bone, and the mental foramen opens below the socket of the first deciduous molar tooth. The angle is obtuse (175°), and the condyloid portion is nearly in line with the body. The coronoid process is relatively large and projects above the level of the condyle.

After birth (fig. 338 C, D) the two halves of the bone become joined at the symphysis from below upwards, in the first year; but a trace of separation may be visible in the beginning of the second year, near the alveolar margin. The body elongates, but more especially behind the mental foramen, to provide space for the three additional teeth developed in this part. The depth of the body increases by growth of the alveolar part of the bone, to afford room for the roots of the teeth, and by thickening of the subalveolar portion. After the second dentition the mandibular canal is situated a little above the level of the mylohyoid line, and the mental foramen occupies the position usual to it in the adult. By the fourth year the angle is reduced to about 140°. As the mandible increases in size, bone is laid down along the posterior borders of the ramus and the coronoid process, while at the same time absorption of bone is occurring along their anterior borders. This process of remodelling goes on continuously until the bone has reached its adult size, and it enables the alveolar part to lengthen sufficiently to provide the necessary space for the permanent molar teeth.

In the adult (fig. 338 E) the alveolar and subalveolar portions of the body are of about equal depth. The mental foramen opens midway between the upper and lower borders of the bone, and the mandibular canal runs nearly parallel with the mylohyoid line. The ramus is almost vertical in direction, the angle measuring from 110° to 120°.

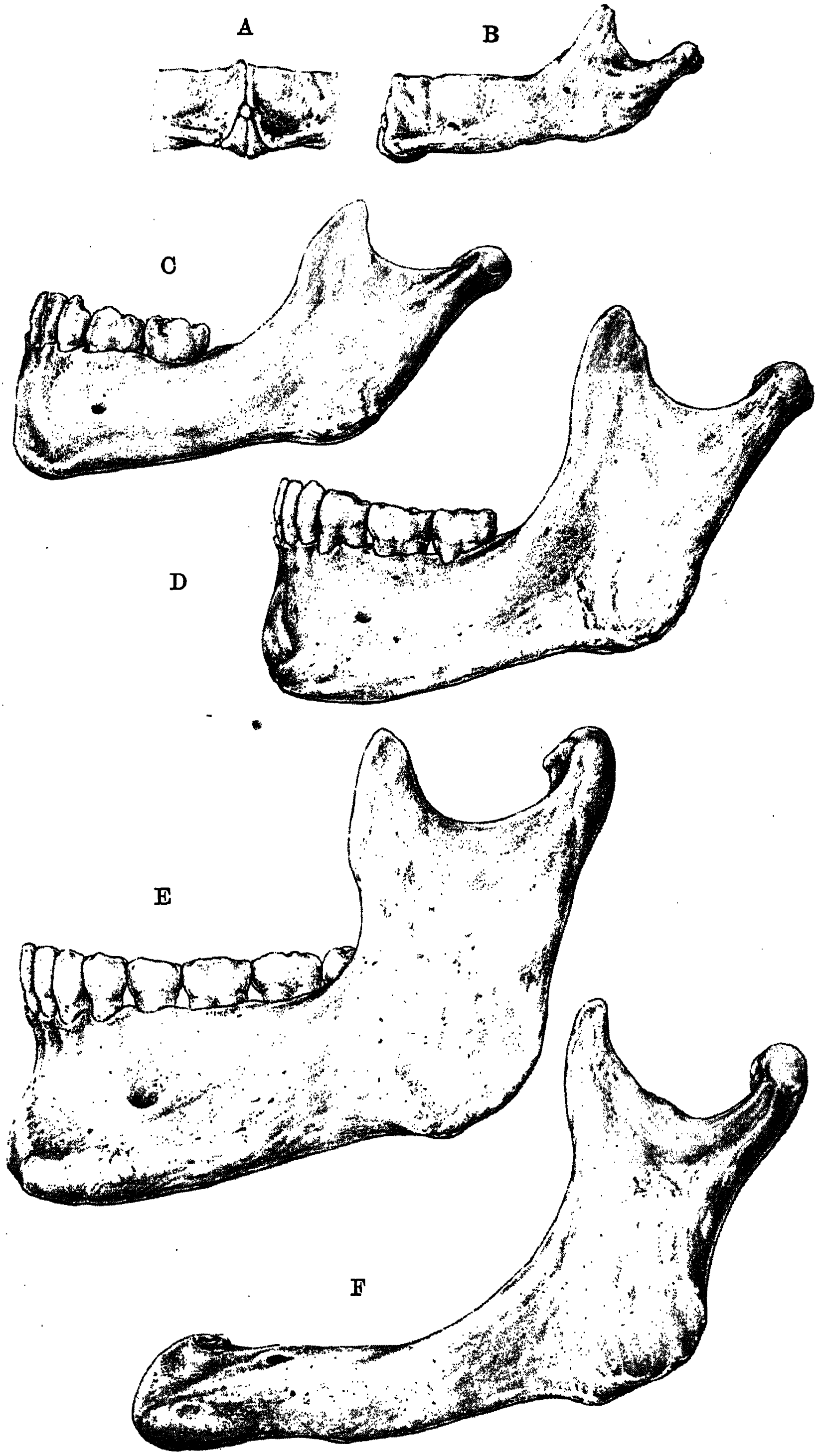
In old age (fig. 338 F) the bone is reduced in size. Following the loss of the teeth the alveolar part is absorbed, and consequently the mandibular canal and the mental foramen are close to the alveolar border. The ramus is oblique in direction, the angle measures about 140°, and the neck of the mandible is more or less bent backwards.† The process of absorption affects chiefly the

* A. Low, *Proceedings of the Anatomical and Anthropological Society of the University of Aberdeen,* 1905, and *Journal of Anatomy and Physiology,* vol. xliv., and E. Fawcett, *Journal of the American Medical Association,* September 2, 1905.

† For further information as to the growth of the jaws and face, consult :—

1. 'The Growth of the Jaws and Face,' by Keith and Campion, *Dental Record,* 1922.
2. Lectures on *The Growth and Diseases of the Jaws, etc.,* by Fawcett, Brash, Northcroft and Keith. Published by the Dental Board of the United Kingdom, 1924.
3. 'Facial Development,' by Arthur Thomson, *Dental Record,* 1924.

FIG. 338.—The mandible at different periods of life.



A, at birth. Anterior aspect, showing the ossicula mentalia. B, at birth. Left lateral aspect. C, at four years. Full milk dentition. D, at eight years. The permanent incisor and first molar teeth have erupted ; the milk molars are in process of being shed. E, adult. F, old age.

thinner of the two alveolar walls and, after its completion, a linear *alveolar ridge* is found on the alveolar border of the bone. In the mandible the labial wall is the thinner in the incisor and canine regions, but it is the lingual wall which is the weaker in the molar region. The alveolar ridge lies therefore within the line of the teeth in the incisor region but lies outside that line in the molar region, forming a curve which is wider than the curve of the line of the teeth and intersects it on each side in the premolar region. In the maxilla, however, the labial wall is everywhere the thinner and, after absorption, the alveolar ridge lies wholly within the curve of the line of the teeth.

THE HYOID BONE [OS HYOIDEUM]

The **hyoid bone** (fig. 339) is U-shaped and is suspended from the tips of the styloid processes of the temporal bones by the stylohyoid ligaments. It has a body, two greater and two lesser cornua.

The **body** or middle part of the hyoid bone is of a quadrilateral form. Its *anterior surface* is convex and directed forwards and upwards. Its upper part is crossed by a well-marked ridge which has a slight downward convexity, and in many cases a vertical median ridge divides the body into lateral halves. The portion of the vertical ridge above the transverse line is present in the majority of specimens, but that below the transverse line is rarely seen. The *posterior surface* is smooth, concave, directed backwards and downwards, and separated from the epiglottis by the thyrohyoid membrane and a quantity of loose areolar tissue ; a bursa intervenes between the bone and the membrane. In early life the *lateral extremities* of the body are connected to the greater cornua by primary cartilaginous joints, but after middle life they are usually united by bone.

FIG. 339.—The hyoid bone. Antero-superior aspect.

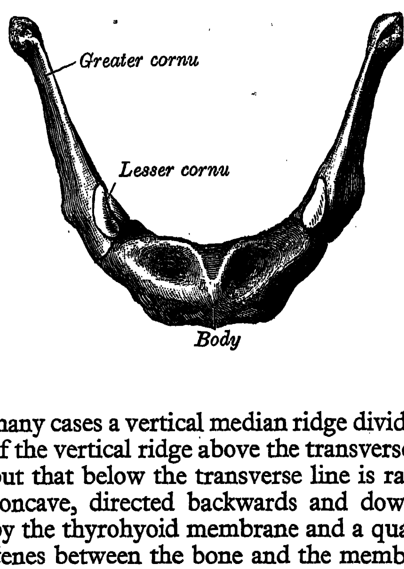
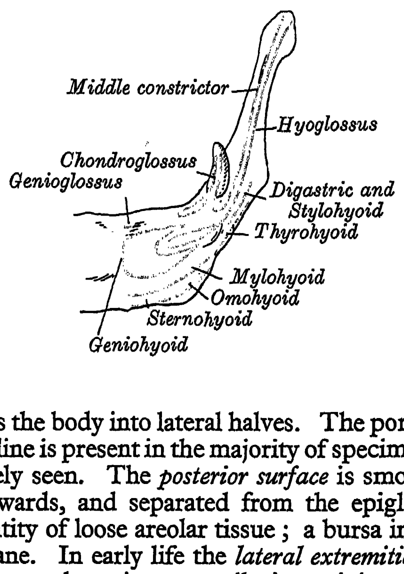


FIG. 340.—A sketch of left half of the hyoid bone to show the muscular attachments.



The **greater cornua** of the hyoid bone project backwards from the lateral limits of the body; they are flattened from above downwards and diminish in size from before backwards. Each cornu ends posteriorly in a tubercle. Close to its lateral border the *upper surface* is rough for muscular attachments.

The **lesser cornua** of the hyoid bone are two small, conical eminences attached by their bases at the angle of junction of the body and greater cornua. They are connected to the body of the bone by fibrous tissue and occasionally to the greater cornua by synovial joints, which usually persist throughout life, but occasionally become ankylosed.

Particular features.—The *anterior surface* of the **body** gives insertion to the geniohyoid muscle in the greater part of its extent both above and below the transverse ridge; a portion of the origin of the hyoglossus muscle invades the lateral margin of the geniohyoid area (fig. 340). The lower part of this surface gives insertion to the mylohyoid muscle, and below that to the sternohyoid medially and the omohyoid laterally. The *superior border*

of the body is rounded and gives attachment to the lowest fibres of the genioglossi, to the hyo-epiglottic ligament and to the thyrohyoid membrane. The *inferior border* gives insertion to the sternohyoid medially and the omohyoid laterally, and sometimes to the medial fibres of the thyrohyoid muscle. It gives attachment also to the levator glandulæ thyreoideæ, when that muscle is present.

The *upper surface* of the **greater cornu** gives origin to the middle constrictor of the pharynx and, more laterally, to the hyoglossus muscle, both of which extend throughout its whole length. Near the junction of the cornu with the body the stylohyoid muscle is inserted lateral to the hyoglossus muscle, and a little posterior to this insertion the fibrous loop through which the tendon of the digastric muscle runs is attached to the bone. The *medial border* gives attachment to the thyrohyoid membrane; the lateral border receives, anteriorly, the insertion of the thyrohyoid muscle. The inferior surface, which is oblique, is separated from the thyrohyoid membrane by some fibro-areolar tissue.

The posterior and lateral aspects of the **lesser cornu** give origin to fibres of the middle constrictor muscle of the pharynx. Its apex gives attachment to the stylohyoid ligament, which is often ossified in part. The medial aspect of its base gives origin to the chondroglossus muscle.

Ossification.—The hyoid bone is developed from the cartilages of the second and third branchial or visceral arches—the lesser cornua from the second, the greater cornua from the third, and the body from the fused ventral ends of both (p. 99). It is ossified from six centres: a pair for the body, and one for each cornu. Ossification commences in the greater cornua towards the end of intrauterine life, in the body before or shortly after birth, and in the lesser cornua during the first or second year, or later.

THE CRANIAL BONES [OSSA CRANII]

The Occipital Bone [Os Occipitale]

The **occipital bone** (figs. 341-343), situated at the posterior and inferior part of the cranium, is trapezoid in shape and concave forwards. It encloses a large oval aperture, termed the *foramen magnum*, through which the cranial cavity communicates with the vertebral canal. The expanded plate above and behind this foramen is named the *squamous part*; the thick, somewhat quadrilateral piece in front of it is called the *basilar part*; that on each side of the foramen is named the *condylar part* (lateral portion).

The **squamous part** of the occipital bone, situated above and behind the foramen magnum, is curved from above downwards and from side to side.

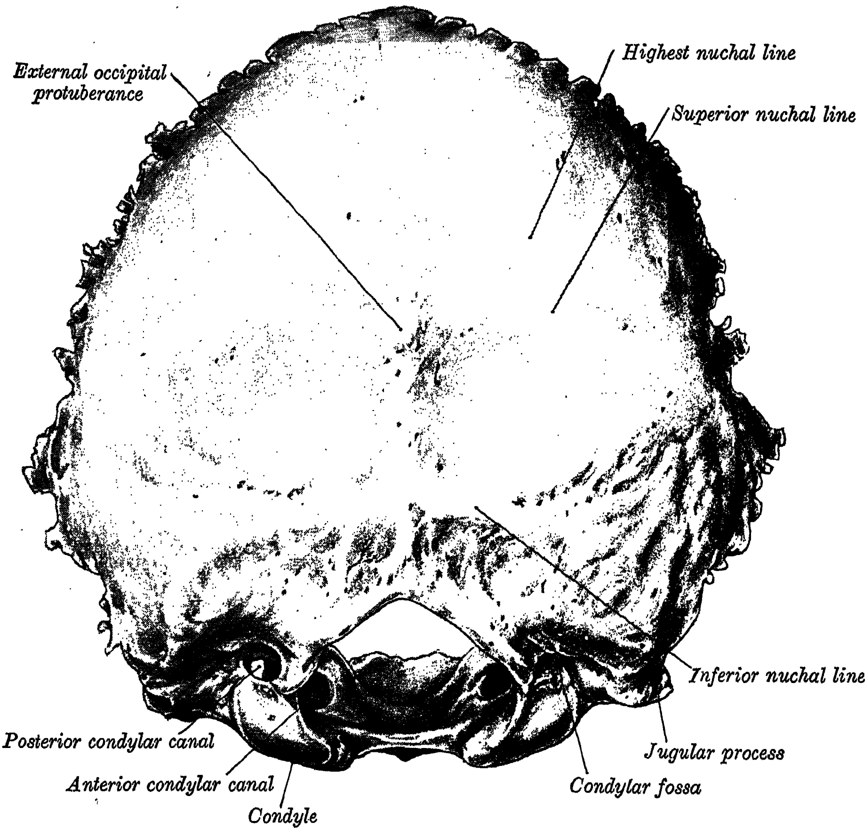
The *external surface* is convex and presents, midway between the summit of the bone and the foramen magnum, a prominence termed the *external occipital protuberance*. Extending laterally from this on each side are two curved lines, one a little above the other. The upper line, faintly marked and often absent, is named the *highest nuchal line*, and to it the epicranial aponeurosis (galea aponeurotica) is attached. The lower line is termed the *superior nuchal line*. The part of the external surface above the highest nuchal lines is smooth, and covered with the occipital belly of the occipitofrontalis muscle. The part below the highest nuchal lines is rough and irregular for the attachment of several muscles. From the external occipital protuberance a ridge, termed the *external occipital crest*, often faintly marked, descends to the foramen magnum, and affords attachment to the ligamentum nuchæ; running laterally from the middle of this line on each side is the *inferior nuchal line*. The superior nuchal line gives origin to the occipitalis and trapezius, and insertion to the sternomastoid and splenius capitis (fig. 342); into the surface between the superior and inferior nuchal lines the semispinalis capitis and the obliquus capitis superior are inserted; the inferior nuchal line and the area below it receive the insertions of the rectus capitis posterior major and minor muscles. The posterior atlanto-occipital membrane is attached around the posterolateral part of the foramen magnum, immediately outside the margin of the foramen.

The *internal surface* of the squamous part is deeply concave, and is divided into four fossæ by an irregular elevation, termed the *internal occipital protuberance*. The upper two fossæ are triangular, and lodge the posterior ends of the occipital lobes of the cerebrum; the lower two are quadrilateral and support the hemispheres of the cerebellum. A wide groove, with raised edges, extends upwards from the protuberance to the superior angle of the bone; it lodges the hinder part of the superior sagittal sinus and is termed the *sagittal sulcus*; to the margins of this sulcus the posterior part of the falx cerebri is attached. A prominent ridge, named the *internal occipital crest*, runs downwards and forwards from the protuberance; it gives attachment to the falx cerebelli, and bifurcates near the foramen

magnum; the occipital sinus, which is sometimes duplicated, lies in the attached margin of the falx. At the lower part of the internal occipital crest a small depression is sometimes distinguishable; it is termed the *vermian fossa,* since it is occupied by part of the inferior vermis of the cerebellum. On each side a wide *transverse sulcus* extends laterally from the internal occipital protuberance; these sulci accommodate the transverse sinuses, and their margins give attachment to the tentorium cerebelli. The right transverse sulcus is usually larger than the left and is continuous with the sagittal sulcus; but the left may be larger than the right, or the two may be almost equal in size. The angle of union of the superior sagittal and transverse sinuses is named the *confluence of the sinuses,* and its position is indicated by a depression on one or other side of the protuberance.

FIG. 341.—The occipital bone. Posterior aspect.

The posterior condylar canal was present on the left side only in this specimen.



The *superior angle* of the squamous part articulates with the posterior superior angles of the parietal bones, and corresponds in position with the *posterior fontanelle* (*occipital fonticulus*) of the fœtal skull. The *lateral angles* are at the ends of the transverse sulci; each is received into the interval between the parietal bone and the mastoid part of the temporal bone. The *lambdoid* or *superior borders* extend from the superior to the lateral angles; they are serrated for articulation with the occipital borders of the parietal bones, and by this union form the lambdoid suture. The *mastoid* or *inferior borders* extend from the lateral angles to the jugular processes; each articulates with the mastoid portion of the corresponding temporal bone.

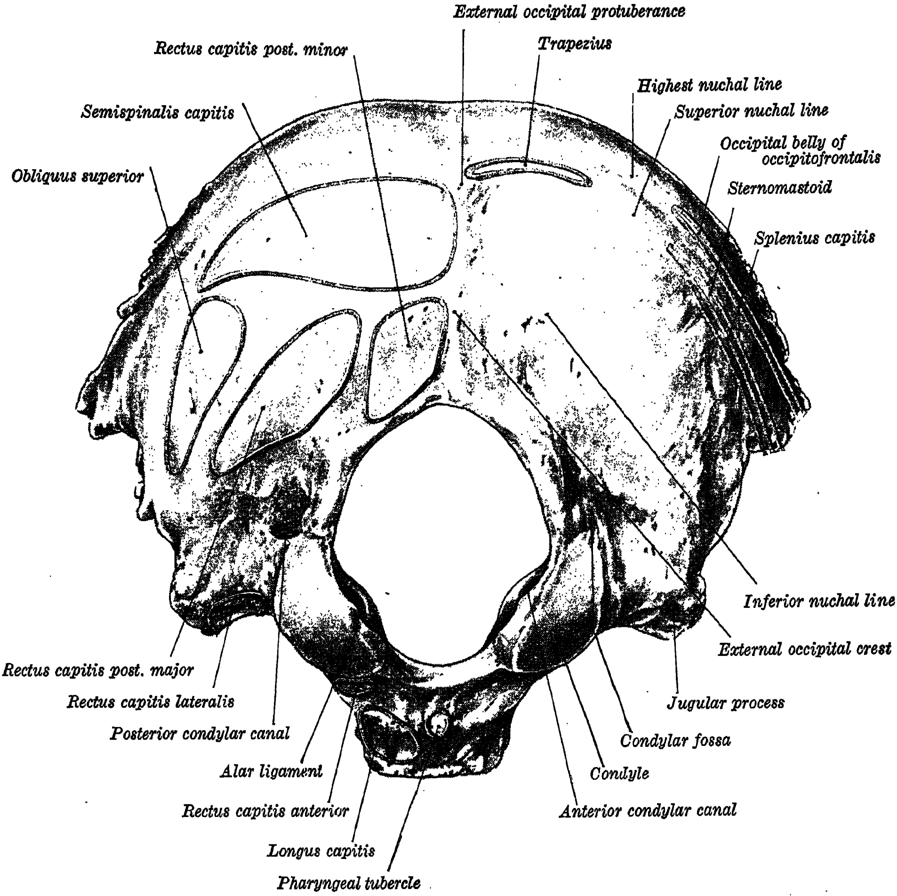
The **basilar part** of the occipital bone extends forwards and upwards from the foramen magnum, and presents *in front* a more or less quadrilateral surface. In the young skull this surface is rough and uneven and is joined to the body of the sphenoid bone by a plate of cartilage. By the twenty-fifth year this plate of cartilage has undergone ossification and the occipital and sphenoid bones are fused.

On the *inferior surface* of the basilar part, about 1 cm. in front of the foramen magnum, a small elevation, termed the *pharyngeal tubercle,* gives attachment to the fibrous raphe of the pharynx. The longus capitis is inserted into the bone lateral to the pharyngeal

tubercle, and the rectus capitis anterior into a small depression in front of the occipital condyle. The anterior margin of the foramen magnum gives attachment to the anterior atlanto-occipital membrane.

The *superior surface* of the basilar part consists of a broad, shallow groove which inclines upwards and forwards from the anterior border of the foramen magnum ; it supports the medulla oblongata and the lower part of the pons, and near the margin of the foramen gives attachment to the membrana tectoria and the apical ligament. On the lateral margins of this surface the *inferior petrosal sulci* are occupied by the inferior petrosal sinuses, and below each of these sulci the lateral margin of the basilar part is rough for articulation with the petrous part of the temporal bone.

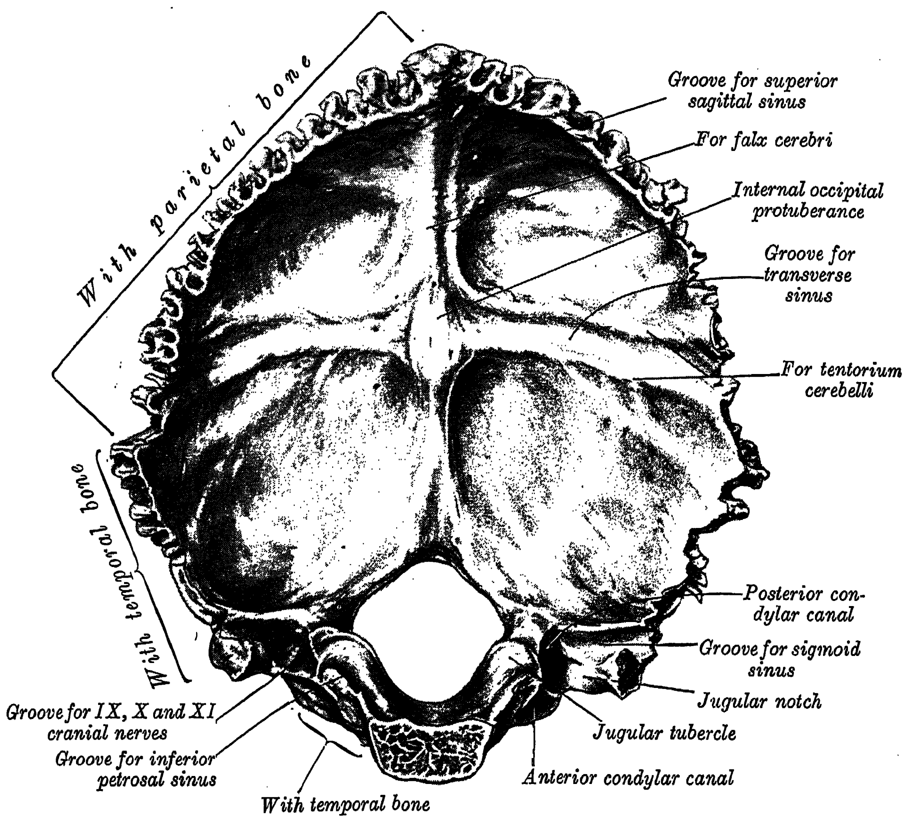
FIG. 342.—The occipital bone. Inferior aspect.
Drawn from the same specimen as fig. 341.



The **condylar parts** (**lateral parts**) of the occipital bone are situated at the sides of the foramen magnum ; on their *inferior surfaces* the *occipital condyles* form two oval processes for articulation with the superior facets of the atlas vertebra. They are oval or reniform in shape, with their long axes running forwards and medially, so that their anterior ends are closer together than their posterior and encroach on the basilar portion of the bone ; the posterior ends extend back to the level of the middle of the foramen magnum. The articular surfaces of the condyles are convex from before backwards and from side to side ; they look downwards and laterally, and are occasionally constricted near their centres. On the medial side of each a rough impression or tubercle gives attachment to the alar ligament. Above the anterior part of each condyle the bone presents the *anterior condylar* (*hypoglossal*) *canal,* which begins on the cranial surface of the bone a short distance above the anterior part of the foramen magnum, and is directed laterally and forwards. It may be partially or completely divided into two by a spicule of bone ; it gives exit to the hypoglossal nerve, and entrance to a meningeal branch of the ascending pharyngeal artery.

A depression, termed the *condylar fossa,* lies behind the condyle and receives the posterior margin of the corresponding superior facet of the atlas when the head is bent backwards; the floor of this fossa is sometimes perforated by the *posterior condylar canal,* through which an emissary vein passes from the sigmoid sinus. The *jugular process* extends laterally from the posterior half of the condyle. It is a quadrilateral plate of bone, indented in front by the *jugular notch,* which, in the articulated skull, forms the posterior part of the jugular foramen. The jugular notch is sometimes divided into two by a bony spicule named the *intrajugular process,* which projects forwards and laterally. The under surface of the jugular process is rough and gives attachment to the rectus capitis lateralis; from this surface an eminence, termed the *paramastoid process,* sometimes projects downwards, and may be of sufficient length to articulate with the transverse process of the atlas. Laterally the jugular process

FIG. 343.—The occipital bone. Internal aspect.



presents a rough quadrilateral or triangular area which is joined to the jugular surface of the temporal bone by a plate of cartilage; after the age of twenty-five this plate tends to ossify.

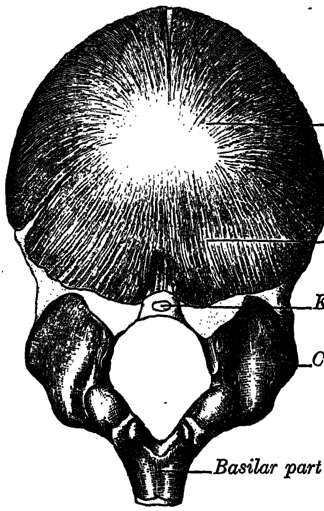
On the *superior surface* of the condylar part an oval eminence, termed the *tuberculum jugulare,* overlies the anterior condylar canal; its posterior part often presents a shallow furrow for the glossopharyngeal, vagus, and accessory nerves. On the superior surface of the jugular process a deep groove curves medially and forwards around an upwardly directed, hook-shaped process and ends at the jugular notch; it lodges the terminal part of the sigmoid sinus. Close to the medial margin of the groove the posterior condylar canal opens into the posterior cranial fossa.

The *foramen magnum* is a large oval aperture with its long diameter in the median plane. The foramen is wider behind than in front, where it is encroached upon by the occipital condyles. The structures which it transmits are enumerated on p. 263.

Structure.—The occipital, like the other cranial bones, consists of two compact lamellæ, called the *outer* and *inner tables,* between which there is spongy substance or *diploë*; the bone is thick at the ridges, protuberances and condyles, and at the anterior portion of the basilar part; in the lower parts of the inferior fossæ it is thin, semitransparent, and devoid of diploë.

Ossification (fig. 344).—Above the highest nuchal line the squamous part is developed in membrane, and is ossified from two centres, one appearing on each side of the median plane about the second month of intrauterine life; this part may remain separate throughout life, and is then known as the *interparietal bone*. The rest of the occipital bone is preformed in cartilage. Below the highest nuchal line, the squamous part is ossified from two centres, which appear about the seventh week of intrauterine life and soon unite to form a single piece. Union of the upper and lower portions of the squamous part takes place in the third month of intrauterine life, but their line of union can be recognised in the bone at birth (fig. 344). An occasional centre appears in the posterior margin of the foramen magnum about the sixteenth week (Kerckring); it unites with the rest of the squamous part before birth. Each of the condylar parts ossifies from a single centre, which appears during the eighth week of intrauterine life. The basilar portion is ossified from one centre, which appears about the sixth week of intrauterine life. About the fourth year the squamous part unites with the condylar portions, and about the sixth year the bone consists of a single piece. Between the eighteenth and twenty-fifth years the occipital and sphenoid bones unite to form a single bone.

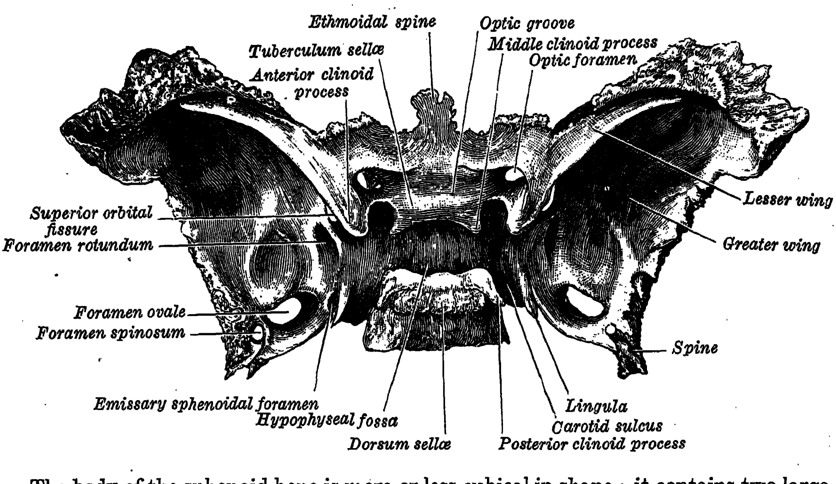
Fig. 344.—The occipital bone at birth. External surface.



The Sphenoid Bone [Os Sphenoideum]

The **sphenoid bone** (figs. 345 to 347) is situated at the base of the skull, in front of the temporal bones and the basilar part of the occipital bone. In shape it resembles a bat with wings outstretched, and consists of a central portion or body, two greater and two lesser wings, which pass laterally from the sides of the body, and two pterygoid processes, which are directed downwards from the adjoining parts of the body and greater wings.

Fig. 345.—The sphenoid bone. Superior surface.



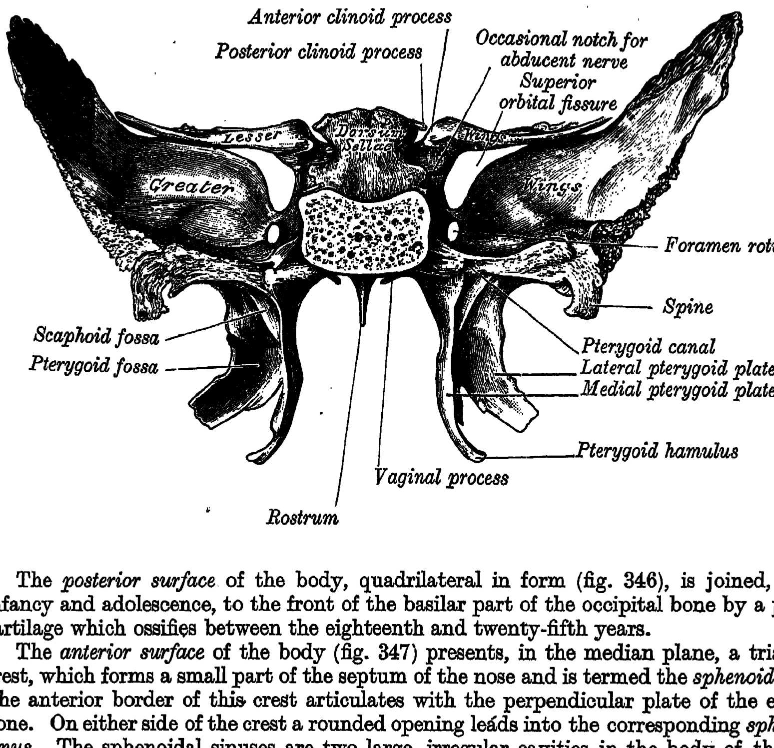
The body of the sphenoid bone is more or less cubical in shape; it contains two large air-sinuses, which are separated from each other by a septum.

The *cerebral* or *superior surface* of the body (fig. 345) articulates in front with the cribriform plate of the ethmoid bone. Anteriorly the surface is smooth and is termed the *jugum sphenoidale*; it supports the posterior ends of the gyri recti and the olfactory tracts. It is bounded behind by a ridge, which forms the anterior border of a transverse groove, termed the *optic groove* (sulcus chiasmatis); this sulcus leads laterally to the *optic foramen* on each

side. Posterior to the groove there is a more or less oval elevation, termed the *tuberculum sellæ*; and behind this a deep depression, termed the *sella turcica,* the deepest part of which lodges the hypophysis cerebri and is known as the *hypophyseal fossa.* The anterior boundary of the sella turcica is completed laterally by two small eminences, called the *middle clinoid processes,* whilst the posterior boundary is formed by a square plate of bone, termed the *dorsum sellæ*; the superior angles of this plate end in two tubercles, termed the *posterior clinoid processes,* which vary considerably in form and size and give attachment to the fixed margin of the tentorium cerebelli. On each side of the body below the dorsum sellæ a small projection articulates with the apex of the petrous portion of the temporal bone and is termed the *petrosal process.* The sloping area behind the dorsum sellæ is termed the *clivus,* and is uninterruptedly continuous with the superior surface of the basilar portion of the occipital bone in the adult skull; it supports the upper part of the pons.

The *lateral surfaces* of the body are united with the greater wings and with the medial pterygoid plates. Above the attachment of each wing a broad groove, termed the *carotid sulcus,* forms a curve somewhat like the italic letter *f*; it lodges the internal carotid artery and the cavernous sinus. The carotid sulcus is deepest at its posterior end, where it is overhung medially by the petrosal process, and is limited laterally by a sharp margin called the *lingula*; the latter is continued backwards to overlie the posterior opening of the pterygoid canal.

FIG. 346.—The sphenoid bone. Posterior aspect.



The *posterior surface* of the body, quadrilateral in form (fig. 346), is joined, during infancy and adolescence, to the front of the basilar part of the occipital bone by a plate of cartilage which ossifies between the eighteenth and twenty-fifth years.

The *anterior surface* of the body (fig. 347) presents, in the median plane, a triangular crest, which forms a small part of the septum of the nose and is termed the *sphenoidal crest.* The anterior border of this crest articulates with the perpendicular plate of the ethmoid bone. On either side of the crest a rounded opening leads into the corresponding *sphenoidal sinus.* The sphenoidal sinuses are two large, irregular cavities in the body of the bone, separated from each other by a bony septum which is commonly bent to one side or the other. They vary considerably in form and size,* are seldom symmetrical, and are often partially subdivided by bony laminæ. A lateral recess may extend from one or other sinus into the greater wing and lingula†; the sinuses occasionally reach into the basilar part of the occipital bone nearly as far as the foramen magnum. In the articulated skull they are closed in front and below by the *sphenoidal conchæ* (p. 293), but a round opening is

* Logan Turner (*The Accessory Sinuses of the Nose,* 1901) gives the following measurements for an adult sphenoidal sinus of average size: height, 2 cm.; breadth, 1·8 cm.; anteroposterior depth, 2·1 cm. Onodi (*The Accessory Sinuses of the Nose in Children,* 1911) states that in the new-born infant their height is 4 mm. and their width 2 mm., while at the eighth year of life their height is from 8 to 12 mm., and their width 11 mm.

† V. Z. Cope (*Journal of Anatomy and Physiology,* vol. li. part ii.) found a well-marked lateral recess in 72 out of 292 sinuses examined, and pointed out that the hypophysis cerebri, the anterior part of the internal carotid artery, the optic and maxillary nerves, and the nerve of the pterygoid canal may give rise to elevations in the walls of the sinuses.

left in the anterior wall of each sinus, by which it communicates with the spheno-ethmoidal recess of the nasal cavity, and occasionally with the posterior ethmoidal sinuses. Each half of the anterior surface of the body of the sphenoid bone consists of two parts: (*a*) an upper and lateral depressed area, which completes, with the labyrinth of the ethmoid bone, the posterior ethmoidal sinuses; its lateral margin articulates with the orbital plate (lamina papyracea) of the ethmoid bone above, and with the orbital process of the palatine bone below; (*b*) a lower and medial, smooth, triangular area, which forms the posterior part of the roof of the nose; near its superior angle is the orifice of the sphenoidal sinus.

The *inferior surface* of the body presents in the median plane a triangular spine, termed the *sphenoidal rostrum* (fig. 346), which, in the articulated skull, projects into a deep fissure between the anterior parts of the alæ of the vomer. The posterior, triangular parts of the sphenoidal conchæ extend backwards on the sides of the rostrum, and articulate with the alæ of the vomer. On each side of the posterior part of the rostrum, and immediately behind the apex of the sphenoidal concha, a thin lamina, named the *vaginal process*, projects medially from the base of the medial pterygoid plate, with which it will be described.

The **greater wings** of the sphenoid bone are two strong processes which curve upwards and laterally from the sides of the body. The posterior part of each is triangular and fits into the angle between the petrous portion of the temporal bone and the squamous part; a small, sometimes pointed, process named the *spine* projects downwards from the apex of this triangular portion; on its medial side there is usually a small groove, directed downwards and forwards, for the chorda tympani nerve. The tip of the spine gives attachment to the sphenomandibular ligament, and a part of the tensor palati muscle. The medial side of the spine forms part of the lateral wall of the groove which lodges the pharyngotympanic (auditory) tube on the external surface of the base of the skull.

The *cerebral surface* of the greater wing (fig. 345) forms part of the floor of the middle fossa of the skull; it is deeply concave and presents depressions corresponding with the convolutions of the anterior part of the temporal lobe of the brain. At its anteromedial part the *foramen rotundum* gives passage to the maxillary nerve. Behind and lateral to this foramen the *foramen ovale* transmits the mandibular nerve, the accessory meningeal artery, and sometimes the lesser superficial petrosal nerve.* Medial to the foramen ovale, a small aperture, termed the *emissary sphenoidal foramen* (*foramen Vesalii*) is present on one or both sides in nearly 40 per cent. of skulls; it opens below at the lateral side of the scaphoid fossa and transmits a small vein from the cavernous sinus. In the posterior angle, anteromedial to the spine, there is a short canal, termed the *foramen spinosum*, which transmits the middle meningeal artery and the nervus spinosus.

The *lateral surface* of the greater wing (fig. 317) is convex from above downwards, and is divided by a transverse ridge, termed the *infratemporal crest*, into an upper or temporal and a lower or infratemporal surface. The *temporal surface*, concave from before backwards, forms a portion of the temporal fossa and gives origin to a part of the temporalis muscle. The *infratemporal surface* is concave and directed downwards; it forms a part of the infratemporal fossa and, together with the infratemporal crest, gives origin to the upper head of the lateral pterygoid muscle. It is pierced by the foramen ovale and foramen spinosum, and its posterior part bears the spine of the sphenoid bone. Medial to the anterior extremity of the infratemporal crest a triangular process serves to increase the attachment of the lateral pterygoid muscle. A ridge runs downwards and medially from this triangular process to the front of the lateral pterygoid plate; it forms the anterior limit of the infratemporal surface and, in the articulated skull, the posterior boundary of the pterygomaxillary fissure.

The *orbital surface* of the greater wing (fig. 347), quadrilateral in shape, is directed forwards and medially and forms the posterior part of the lateral wall of the orbit. Its upper, serrated edge articulates with the orbital plate of the frontal bone; its lateral, serrated margin with the zygomatic bone. Its inferior smooth border forms the posterolateral boundary of the inferior orbital fissure. Its medial sharp margin constitutes the lower boundary of the superior orbital fissure; projecting from near the middle of this margin there is a small tubercle. This tubercle gives attachment to part of the annulus tendineus communis, from which the rectus muscles of the eyeball take origin. Below the medial end of the superior orbital fissure there is a grooved area which forms the posterior wall of the pterygopalatine fossa and is pierced by the foramen rotundum.

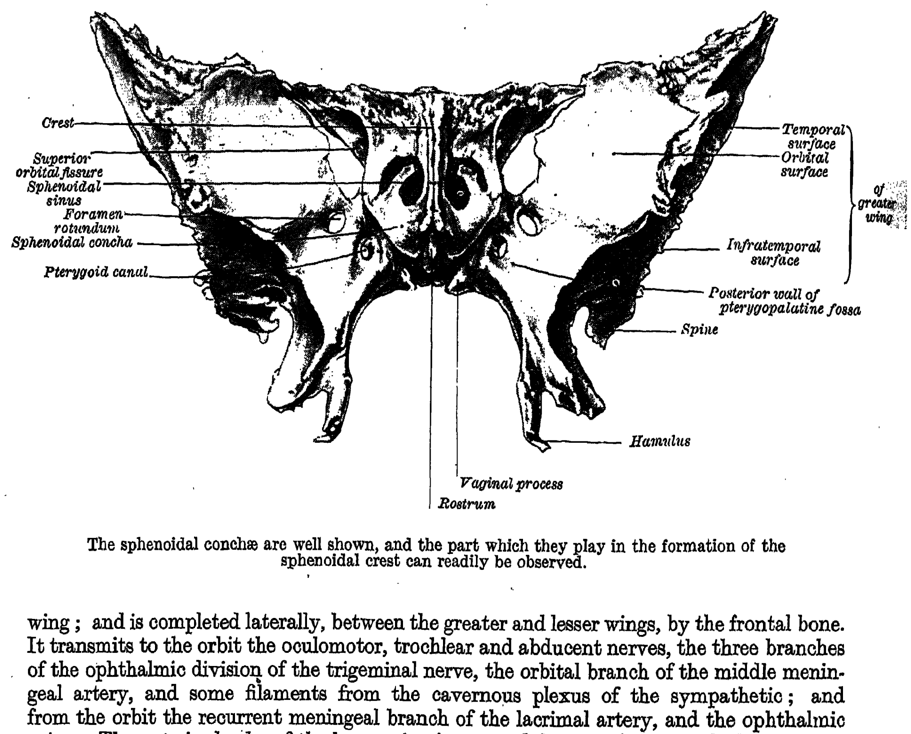
The margin of the greater wing (fig. 345).—The portion of the margin of the greater wing which extends from the body to the spine of the sphenoid is irregular. Its medial half forms the anterior boundary of the *foramen lacerum* and presents the posterior aperture of the pterygoid canal for the passage of the corresponding nerve and artery. Its lateral half articulates, by means of a cartilaginous joint, with the petrous portion of the temporal bone. Between the two bones, on the under surface of the skull, there is a furrow, named the

* The lesser superficial petrosal nerve may pass through a special canal (*canaliculus innominatus*) on the medial side of the foramen spinosum.

sulcus tubæ, which lodges the cartilaginous part of the pharyngotympanic (auditory) tube. Extending forwards from the sphenoidal spine the *squamosal margin* forms a concave, serrated edge, bevelled at the expense of the inner surface below and of the outer surface above, for articulation with the squamous part of the temporal bone. The tip of the greater wing is bevelled at the expense of the inner surface and articulates with the anterior inferior angle of the parietal bone at the pterion. Medial to this there is a triangular rough area, for articulation with the frontal bone; the medial angle of this area is continuous with the sharp edge which forms the lower boundary of the superior orbital fissure, and the anterior angle with the serrated margin for articulation with the zygomatic bone.

The **lesser wings** of the sphenoid bone are two triangular plates which project laterally from the upper and anterior parts of the body and end in sharp points (figs. 345, 346). The *cerebral surface* of each is smooth, and supports a small part of the frontal lobe of the brain. The *inferior surface* forms the posterior part of the roof of the orbit and the upper boundary of the *superior orbital fissure*; it overhangs the anterior part of the middle fossa of the skull. The **superior orbital fissure** is triangular in shape and leads from the cranial cavity into the orbit; it is bounded medially by the body of the sphenoid bone; above, by the lesser wing; below, by the medial margin of the orbital surface of the greater

FIG. 347.—The sphenoid bone of an eight years old child. Anterior aspect.



The sphenoidal conchæ are well shown, and the part which they play in the formation of the sphenoidal crest can readily be observed.

wing; and is completed laterally, between the greater and lesser wings, by the frontal bone. It transmits to the orbit the oculomotor, trochlear and abducent nerves, the three branches of the ophthalmic division of the trigeminal nerve, the orbital branch of the middle meningeal artery, and some filaments from the cavernous plexus of the sympathetic; and from the orbit the recurrent meningeal branch of the lacrimal artery, and the ophthalmic veins. The *anterior border* of the lesser wing is serrated for articulation with the posterior edge of the orbital plate of the frontal bone. The *posterior border* is smooth and projects into the lateral cerebral fissure; the medial end of this border forms the *anterior clinoid process*, which gives attachment to the anterior end of the free border of the tentorium cerebelli. The anterior and middle clinoid processes are sometimes united by a spicule of bone, and when this occurs the end of the groove for the internal carotid artery is converted into a foramen (*caroticoclinoid foramen*). The lesser wing is connected to the body by two roots, the anterior thin and flat, the posterior thick and triangular; the *optic foramen*, which lies between them, transmits the optic nerve and ophthalmic artery to the orbit.

The **pterygoid processes** of the sphenoid (figs. 346, 347), one on each side, descend perpendicularly from the regions where the greater wings unite with the body. Each process consists of a medial and a lateral plate, the upper parts of which are fused anteriorly. The plates are separated below by an angular cleft, termed the *pterygoid fissure*, the rough margins of which articulate with the tubercle (pyramidal process) of the palatine bone. The two plates diverge behind, and the wedge-shaped *pterygoid fossa* between them contains the medial pterygoid and tensor palati muscles. Above this fossa there is a small, oval, shallow depression, named the *scaphoid fossa*, which is formed by the division of the upper

part of the posterior border of the medial pterygoid plate; it gives origin to part of the tensor palati muscle. The anterior surface of the pterygoid process is broad and triangular near its root, where it forms the posterior wall of the pterygopalatine fossa; it is pierced by the anterior orifice of the *pterygoid canal.*

The *lateral pterygoid plate* is broad, thin, and everted; its *lateral surface* forms part of the medial wall of the infratemporal fossa and gives origin to the lower head of the lateral pterygoid; its *medial surface* forms the lateral wall of the pterygoid fossa and gives origin to the greater part of the medial pterygoid muscle. The upper part of the *anterior border* forms the posterior boundary of the pterygomaxillary fissure; the lower part articulates with the palatine bone; its *posterior border* is free.

The *medial pterygoid plate* is narrower and longer than the lateral; its lower extremity curves laterally into a hook-like process, termed the *pterygoid hamulus,* around which the tendon of the tensor palati glides, and to which the pterygomandibular ligament is attached. The *lateral surface* of this plate forms the medial wall of the pterygoid fossa, and the tensor palati lies against it; the *medial surface* constitutes the lateral boundary of the corresponding posterior nasal aperture. Superiorly the medial pterygoid plate is prolonged on to the under surface of the body as a thin lamina, named the *vaginal process,* which articulates anteriorly with the sphenoidal process of the palatine bone and medially with the ala of the vomer. On its under surface there is a furrow, the anterior part of which is converted into a canal by the sphenoidal process of the palatine bone; this canal is named the *palatinovaginal canal,* and transmits the pharyngeal branch of the maxillary (internal maxillary) artery and the pharyngeal nerve from the sphenopalatine ganglion. The posterior margin of the medial pterygoid plate gives attachment in its entire length to the pharyngobasilar fascia, and from the lower end of this margin the superior constrictor muscle of the pharynx takes origin. The upper end of this margin is marked by a small projection named the *pterygoid tubercle,* which lies immediately below the posterior opening of the pterygoid canal. Projecting backwards from near the middle of the margin is an angular process, sometimes termed the *processus tubarius,* which supports the pharyngeal end of the pharyngotympanic (auditory) tube. The anterior margin of the medial pterygoid plate articulates with the posterior border of the perpendicular plate of the palatine bone.

The **sphenoidal conchæ** (fig. 347) are two thin, curved plates, situated at the anterior and lower parts of the body of the sphenoid bone; the upper, concave surface of each forms the anterior wall and a part of the floor of the corresponding sphenoidal sinus. The sphenoidal conchæ are usually more or less destroyed in the process of disarticulating the skull, but, when seen *in situ,* each consists of an anterior, vertical, quadrilateral part and a posterior, horizontal, triangular part. The anterior, vertical portion consists of (*a*) an upper and lateral depressed area, which completes the posterior ethmoidal sinuses and articulates below with the orbital process of the palatine bone; and (*b*) a lower and medial area, smooth and triangular, which forms part of the roof of the nasal cavity, and is perforated near its superior angle by a round opening through which the sphenoidal sinus communicates with the spheno-ethmoidal recess of the nasal cavity. The anterior vertical portions of the two bones meet in the median plane and are protruded forwards as the sphenoidal crest. The horizontal triangular portion of the concha forms a part of the roof of the nasal cavity and completes the sphenopalatine foramen; its medial margin articulates with the rostrum of the sphenoid and with the ala of the vomer; its apex, directed backwards, lies medial to and above the vaginal process of the medial pterygoid plate, and articulates with the posterior part of the ala of the vomer. A small piece of the sphenoidal concha sometimes appears in the medial wall of the orbit, betweeen the orbital plate of the ethmoid in front, the orbital process of the palatine bone below, and the frontal bone above.

Ossification.—Until the seventh or eighth month of intrauterine life the body of the sphenoid consists of two parts—viz. one in front of the tuberculum sellæ, forming the *presphenoidal part,* with which the lesser wings are continuous; the other comprising the sella turcica and dorsum sellæ, forming the *postsphenoidal part,* with which the greater wings and pterygoid processes are associated. A considerable part of the bone is preformed in cartilage. There are six centres for the presphenoidal and eight for the postsphenoidal part.

Presphenoidal part.—About the ninth week a centre of ossification appears for each of the lesser wings, just lateral to the optic foramen; shortly afterwards two centres appear in the presphenoidal part of the body. The sphenoidal conchæ are each developed from a centre which makes its appearance about the fifth month *; at birth, they consist of small triangular laminæ; about the third year they become hollowed out and cone-shaped; about the fourth year they fuse with the labyrinths of the ethmoid, and between the ninth and twelfth years with the sphenoid bone.

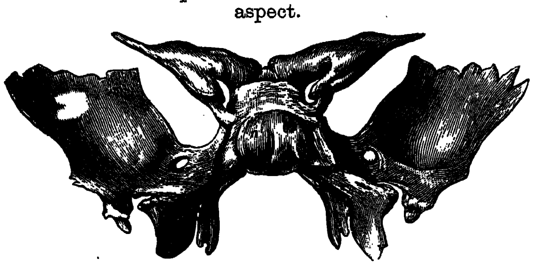
Postsphenoidal part.—The first centres of ossification are those for the greater wings. About the eighth week one appears below the foramen rotundum in the cartilage which forms the base of each wing. This centre forms only the root of the greater wing in the neighbourhod of the foramen rotundum and the pterygoid canal. The whole of the rest of the greater wing is ossified in membrane and the process extends downwards into the

* According to Cleland, each sphenoidal concha is ossified from four centres.

lateral pterygoid plate (Fawcett). About the fourth month, two centres appear in the postsphenoidal part of the body, one on each side of the sella turcica, and fuse about the middle of intrauterine life. Each medial pterygoid plate (with the exception of its hamulus) is ossified in membrane, and its centre probably appears about the ninth or tenth week; the hamulus is chondrified during the third month and almost at once begins to ossify.* The medial and lateral pterygoid plates join about the sixth month. About the fourth month a centre appears for each lingula and speedily joins the rest of the bone.

The presphenoidal and the postsphenoidal parts of the body fuse about the eighth month of intrauterine life, but a wedge-shaped piece of cartilage persists for some time after birth in the lower part of the line of fusion. At birth the bone is in three pieces (fig. 348): a central, consisting of the body and lesser wings, and two lateral, each comprising a greater wing and pterygoid process. In the first year after birth the greater wings and body unite around the margins of the pterygoid canal, and the lesser wings extend medially above the anterior part of the body and meet to form an elevated smooth surface, termed the *jugum sphenoidale*. By the twenty-fifth year the sphenoid and occipital bones are completely fused. In the anterior part of the hypophyseal fossa there are occasionally seen the remains of the *cranio-pharyngeal canal*, through which, in the embryo, the hypophyseal diverticulum of the buccal ectoderm is transmitted (p. 166).

FIG. 348.—The sphenoid bone at birth. Posterior aspect.



Traces of the sphenoidal sinuses are seen as early as the third month of intrauterine life, but they do not attain their full size until after puberty. Although they are usually restricted to the presphenoidal and postsphenoidal parts of the body, the sinuses may invade any part of the bone which is preformed in cartilage.

Certain parts of the sphenoid bone are connected by ligaments which occasionally ossify. The more important of these ligaments are: the *pterygospinous*, stretching between the spine of the sphenoid and the upper part of the lateral pterygoid plate (see *cervical fascia*); the *interclinoid*, joining the anterior to the posterior clinoid process; and the *caroticoclinoid*, connecting the anterior to the middle clinoid process.

Applied Anatomy.—Premature ossification or synostosis of the suture between the pre- and postsphenoidal parts (which normally begin to join at the eighth month) and of the sphenobasilar suture produces a characteristic physiognomy. This is best seen in profile, and consists in an abnormal depression of the bridge of the nose; it is a feature often observed in dwarfs.

The Temporal Bones (Ossa Temporalia)

The **temporal bones** are situated at the sides and base of the skull. Each consists of five parts, viz. the *squamous, mastoid, petrous,* and *tympanic parts*, and the *styloid process*. These represent four morphologically distinct elements which have become fused with one another. The squamous part is a dermal bone, developed to assist in the protection of the cerebrum. The petromastoid portion is preformed in cartilage as a protecting capsule for the membranous labyrinth. The tympanic part, formed in membrane, is homologous with the angular bone, which constitutes a part of the composite lower jaw of many reptilians and bony fishes; it has become incorporated in the skull and adapted to play a part in the provision of a satisfactory mechanism for the transmission of sound-waves in an air medium. The styloid process represents the dorsal end of the skeletal element of the hyoid arch. The fusion of these distinct elements to form the temporal bone and the inclusion of the tympanic cavity within the bone during the process have been dealt with on p. 130.

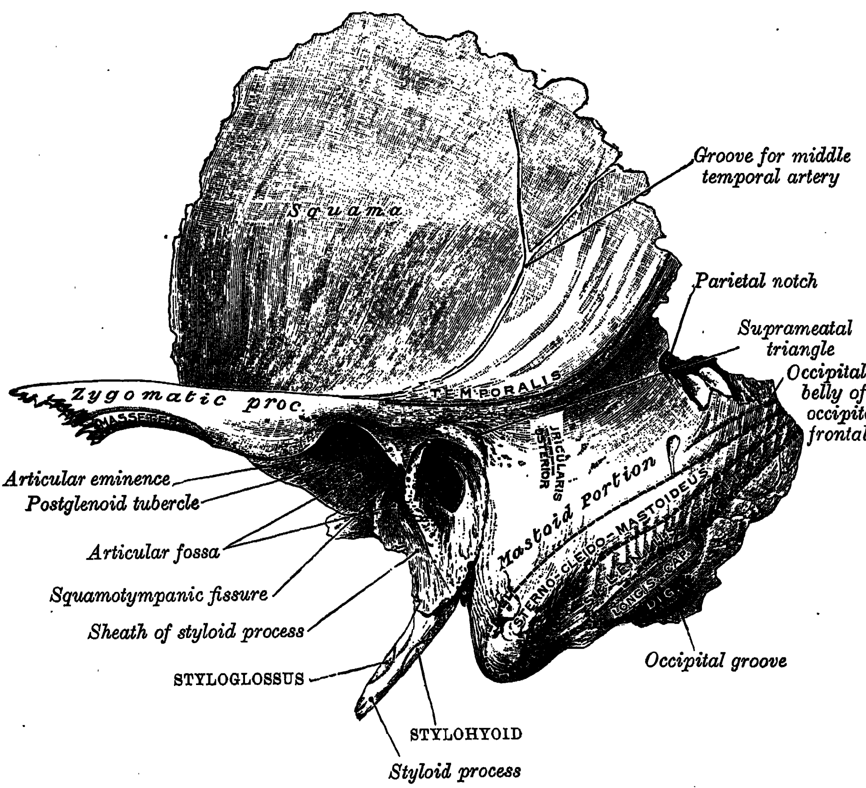
The **squamous part** of the temporal bone forms the anterior and upper part of the bone, and is scale-like, thin and translucent. Its *temporal surface* (fig. 349) is smooth and slightly convex; it forms part of the temporal fossa and gives origin to the temporal muscle; above the opening of the external auditory meatus it is marked by a vertical groove for the middle temporal artery. A curved line, termed the *supramastoid crest*, courses backwards and upwards across its posterior part; it serves for the attachment of the temporal fascia and limits the origin of the temporal muscle. The boundary between the squamous and mastoid portions of the bone lies about 1·5 cm. below the supramastoid crest and is frequently indicated by traces of the original squamomastoid suture; the external surface of this lower part is convex, and from its anterior part the auricularis

* E. Fawcett, *Anatomischer Anzeiger*, March 1905.

posterior takes origin. Between the anterior end of the supramastoid crest and the postero-superior sector of the opening of the external auditory meatus there is a depression, termed the *suprameatal triangle* ; this triangle is an important landmark for the tympanic antrum, which lies medial to it, at a depth of about 1·25 cm. The anterior part of the depression is usually marked by a small projection, termed the *suprameatal spine*.

A long, arched process, termed the *zygomatic process*, or *zygoma*, projects forwards from the lower portion of the temporal surface. The posterior part of this process is triangular in shape and springs from a broad base ; it is directed laterally, and its surfaces are superior and inferior. The process is then twisted forwards and medially, and the surfaces of its anterior portion are therefore medial and lateral. The superior surface of the posterior part is concave, and continuous with the temporal surface of the squamous part ; the inferior surface is bounded by two roots, a *posterior* and an *anterior*, which converge as they approach the anterior part of the process. At the meeting point of the two roots the *tubercle of the root of the zygoma* gives attachment to the temporomandibular ligament. The

FIG. 349.—The left temporal bone. Externa aspect.

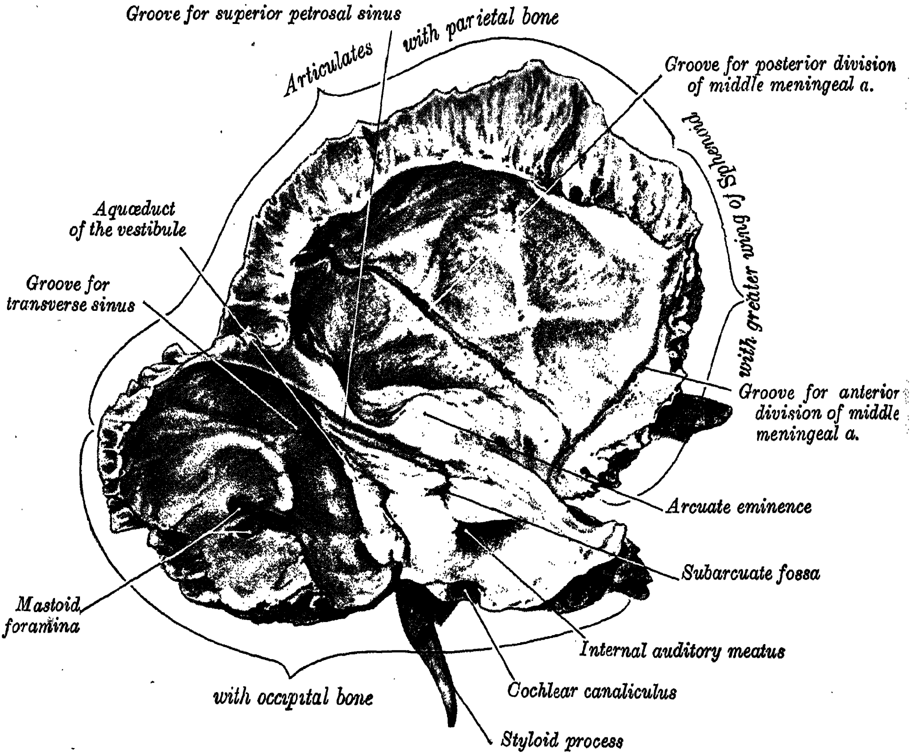


posterior root is prolonged forwards from the surface of the squamous part immediately above the opening of the external auditory meatus ; its upper border is continuous behind with the supramastoid crest. The anterior root juts almost horizontally from the side of the squamous part ; its inferior surface, convex from before backwards, is smooth for articulation with the articular disc of the mandibular joint, and the whole root presents the form of a short semicylindrical bar, named the *articular eminence* (tuberculum articulare). The articular eminence forms the anterior boundary of the articular (mandibular) fossa. Very rarely the squamous part is perforated just above the posterior root of the zygoma. When present, this *squamosal foramen* transmits the petrosquamous sinus (p. 817).

The anterior part of the zygomatic process is thin and flat. The superior border, long and thin, gives attachment to the temporal fascia ; the inferior, short and arched, gives origin to some fibres of the masseter muscle. The lateral surface is convex and subcutaneous ; the medial is concave and gives origin to part of the masseter. The anterior end is deeply serrated and cut obliquely at the expense of the lower border ; it articulates with the temporal process of the zygomatic bone. In front of the articular eminence a small triangular area forms a part of the roof of the infratemporal fossa and is separated from the temporal surface of the squamous part by a ridge ; this ridge is continuous behind with the anterior root of the zygomatic process, and in front, in the articulated skull, with the infratemporal

crest on the greater wing of the sphenoid bone. The *articular fossa* (mandibular fossa) is bounded in front by the articular eminence; it consists of an anterior, articular portion, formed by the squamous part of the temporal bone, and a posterior, non-articular portion, formed by the tympanic part. The articular portion, smooth, oval and deeply concave, articulates with the articular disc of the mandibular joint; the non-articular portion sometimes lodges a small part of the parotid gland. A small, conical eminence, termed the *postglenoid tubercle*, separates the lateral part of the articular portion from the anterior margin of the tympanic part of the bone, and is the representative of a prominent tubercle which, in some mammals, descends behind the condyle of the mandible and prevents its backward displacement; the postglenoid tubercle is sometimes described as the third root of the zygomatic process. The medial part of the articular portion of the fossa is separated from the tympanic part of the bone by the *squamotympanic fissure*, into which projects the lower edge of the downturned anterolateral part of the tegmen tympani of the petrous part of the bone; the *petrotympanic fissure* is situated between this plate and the tympanic

FIG. 350.—The left temporal bone. Internal surface.



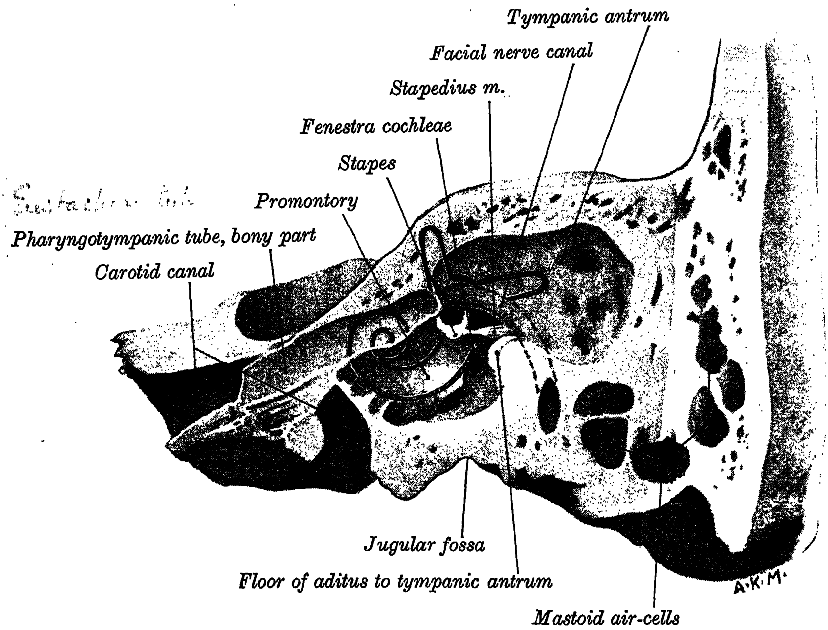
part. This fissure leads into the middle ear or tympanic cavity; it lodges the anterior ligament of the malleus and transmits the anterior tympanic branch of the maxillary (internal maxillary) artery. The medial end of the fissure presents the anterior opening of the *anterior canaliculus for the chorda tympani*. Very rarely a *postglenoid foramen* is present just in front of the external auditory meatus and in the line of fusion of the squamous and tympanic portions of the bone. It replaces the squamosal foramen, already mentioned, and transmits the petrosquamous sinus (p. 817).

The *cerebral surface* of the squama (fig. 350) is concave; it presents depressions corresponding to the convolutions of the temporal lobe of the brain, and grooves for the branches of the middle meningeal vessels; its lower border is united to the anterior surface of the petrous portion but traces of a petrosquamosal suture are frequently seen in the adult bone.

The *superior border* is thin, bevelled at the expense of the cerebral surface, and overlaps the inferior border of the parietal bone, forming with it the squamosal suture. Posteriorly the superior border forms an angle (B.N.A. *parietal notch*) with the mastoid portion of the bone. The *antero-inferior border*, thin above and thick below, articulates with the greater wing of the sphenoid bone; its upper part is bevelled at the expense of the cerebral surface, its lower at the expense of the temporal surface.

The **mastoid portion** forms the posterior part of the temporal bone. Its *outer surface* (fig. 349) is rough and gives attachment to the occipital belly of the occipitofrontalis, and the auricularis posterior muscle. It is frequently perforated near its posterior border by the *mastoid foramen,* which gives exit to a vein from the sigmoid sinus and entrance to a small branch of the occipital artery to the dura mater; the position and size of this foramen are very variable; it may be situated in the occipital bone, or in the suture between the temporal and the occipital bones. The mastoid portion is continued below into a conical projection, named the **mastoid process**; it is larger in the male than in the female. The lateral surface of this process gives insertion to the sternomastoid, splenius capitis, and longissimus capitis; on its medial side there is a deep groove, termed the *mastoid notch,* for the attachment of the posterior belly of the digastric muscle; medial to this notch the shallow *occipital groove* lodges the occipital artery.

FIG. 351.—A section through the left temporal bone in the long axis of the tympanic cavity. The lateral surface of the medial half of the bone is shown.
The duct of the cochlea and the superior and lateral semicircular ducts are shown in blue.



On the *inner surface* of the mastoid portion (fig. 350) there is a deep, curved groove termed the *sigmoid sulcus,* which lodges the sigmoid sinus; near its posterior border it receives the opening of the mastoid foramen. The sigmoid sulcus is separated from the innermost of the mastoid air-cells by a thin lamina of bone which may be partly deficient.

The *superior border* of the mastoid portion is thick and serrated for articulation with the postero-inferior angle of the parietal bone. The *posterior border,* also serrated, articulates with the inferior border of the occipital bone between the lateral angle and jugular process. The mastoid portion is fused with the descending process of the squamous part above; below, it enters into the formation of the posterior wall of the tympanic cavity.

A section of the mastoid process (fig. 351) exhibits a number of spaces, termed the *mastoid air cells,* which vary greatly in size and number. At the upper and front part of the process they are large and irregular, but towards the lower part they diminish in size, while those at the apex of the process are frequently quite small; occasionally they are entirely absent, and the mastoid is then solid throughout. In addition, a large, irregular air-sinus, termed the **tympanic antrum,** is situated at the upper and anterior part of the mastoid portion of the bone; it is lined with a prolongation of the mucous membrane of the tympanic cavity. It is bounded above by a thin plate of bone, termed the *tegmen tympani,* which separates it from the middle cranial fossa; laterally by the portion of the squamous part which lies below the supramastoid crest; its medial wall is related to the lateral semicircular canal of the internal ear. Below and behind, the tympanic antrum communicates with the mastoid air cells; in front, it opens into that portion of the tympanic cavity which is known as the *epitympanic recess.* The tympanic antrum is a cavity

of some considerable size at the time of birth; the mastoid air cells originate as diverticula from the antrum, and begin to appear at or before birth; by the fifth year they are of considerable size, but their development is not completed until puberty. (Pl. I, fig. 1.)

The **petrous portion** of the temporal bone is wedged between the sphenoid and occipital bones at the base of the skull (figs. 319, 324). It is directed medially, forwards, and a little upwards; it has a base, an apex, three surfaces, and three margins. The essential parts of the organs of hearing and equilibration are placed within it.

The *base* is fused with the squamous and mastoid portions, and is partially separated from them by the tympanic antrum.

The *apex*, rough and uneven, is received into the angular interval between the posterior border of the greater wing of the sphenoid bone and the basilar part of the occipital bone; it is pierced by the anterior orifice of the carotid canal and forms the posterolateral boundary of the foramen lacerum.

The *anterior surface* helps to form the floor of the middle cranial fossa and is continuous with the cerebral surface of the squamous part, although remains of the petrosquamosal suture are often distinct even at a late period of life.

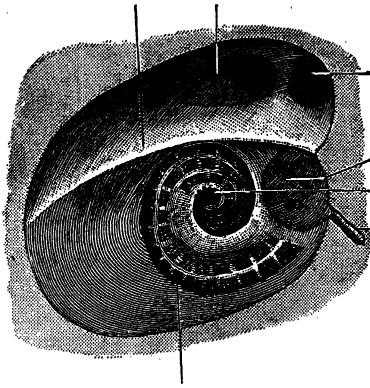
The whole surface is marked by impressions for the gyri of the inferior surface of the temporal lobe of the brain. Immediately behind the apex a slight hollow lodges the trigeminal (semilunar) ganglion and it is termed the *trigeminal impression.* The bone anterior and slightly lateral to the impression forms the roof of the anterior part of the carotid canal; it is often deficient in this situation. An irregular ridge separates the trigeminal impression posteriorly from a second hollow, which forms part of the roof of the internal auditory meatus and covers the cochlea. This concavity is limited behind by an elevation, termed the *arcuate eminence* (fig. 350), which is raised by the superior semicircular canal and, in its lateral part, roofs in the vestibule and the beginning of the facial canal. Between the squamous part on the lateral side and the arcuate eminence and the hollows just described on the medial side the surface is formed by the *tegmen tympani* (fig. 324). This thin plate of bone forms the roof of the tympanic antrum behind and extends forwards above the tympanic cavity and the canal for the tensor tympani muscle. Its lateral margin meets the squamous part at the site of the petrosquamosal suture and turns downwards in front to form the lateral wall of the canal for the tensor tympani and the bony part of the pharyngotympanic (auditory) tube; the lower edge of this downturned portion has already been observed in the floor of the squamotympanic fissure (p. 262). Anteriorly the tegmen tympani presents a narrow groove, which runs backwards and laterally and enters the bone through an opening placed in front of the lateral part of the arcuate eminence. This hiatus transmits the greater superficial petrosal nerve, which runs forwards to the foramen lacerum. A second groove may mark the bone on the lateral side of the one just described; it transmits the lesser superficial petrosal nerve from the tympanic plexus. The posterior slope of the arcuate eminence covers the posterior and lateral semicircular canals, and lateral to it the posterior part of the tegmen tympani roofs in the posterior part of the tympanic antrum.

The *posterior surface* (fig. 350) forms the anterior part of the posterior cranial fossa and is continuous with the inner surface of the mastoid portion. Near the centre of this surface an orifice of varying size leads into the *internal auditory meatus.* This canal, which is about 1 cm. in length, runs laterally; it transmits the facial and auditory nerves and the internal auditory artery. The lateral end of the internal auditory meatus is separated from the internal ear by a vertical plate, which is divided into two unequal portions by a horizontal crest, termed the *transverse crest* (fig. 352). Below the posterior part of the crest, and situated in the *inferior vestibular area,* several openings are present for the transmission of the nerves to the saccule; below and behind this area the *foramen singulare* gives passage to the nerve to the posterior semicircular duct. Below the anterior part of the transverse crest, a number of small spirally arranged openings constituting the *tractus spiralis foraminosus,* encircle the *central canal of the cochlea*; these openings together with the central canal transmit the nerves to the cochlea. The portion above the transverse crest displays, behind, the *superior vestibular area,* pierced by a series of small openings for the passage of the nerves to the utricle and the superior and lateral semicircular ducts, and in front, the *facial area,* with one large opening which is the commencement of the *canal for the facial nerve.* Behind the opening of the meatus there is a small slit almost hidden by a thin plate of bone; it leads to a canal, named the *aquæduct of the vestibule,* which contains the saccus and ductus endolymphaticus together with a small artery and vein. Above and between these two openings an irregular depression, termed the *subarcuate fossa,* lodges a process of the dura mater and transmits a small vein; in the infant this depression is represented by a large fossa which extends as a short, blind tunnel under the superior semicircular canal.

The *inferior surface* (fig. 353), rough and irregular, forms part of the external surface of the base of the skull. It presents the following parts for examination: (1) near the apex there is a quadrilateral rough surface, which serves partly for the attachment of the levator palati (levator veli palatini) muscle and the cartilaginous portion of the pharyngotympanic (auditory) tube, and partly for connexion with the basilar part of the occipital bone through the intervention of some dense fibrous tissue; (2) behind this a large, nearly circular

aperture, leads into the *carotid canal*; this canal runs at first vertically, and then, making a bend, is directed horizontally forwards and medially; it transmits into the cranium the internal carotid artery and the carotid plexus of nerves; (3) behind this opening there is a deep depression, termed the *jugular fossa*, of variable depth and size in different skulls; it lodges the superior bulb of the internal jugular vein; (4) in front of the medial part of the jugular fossa and directly below the internal auditory meatus, the bone is marked by a triangular depression, which lodges the inferior (petrous) ganglion of the glossopharyngeal nerve; at the apex of this notch a small opening leads into the *cochlear canaliculus*, which lodges the aqueduct of the cochlea and a tubular prolongation of the dura mater and transmits a vein from the cochlea to join the internal jugular vein; through the aqueduct the perilymph of the labyrinth is enabled to drain away into the subarachnoid space; (5) on the bony ridge dividing the carotid canal from the jugular fossa there is a small *canaliculus for the tympanic nerve*, which is derived from the glossopharyngeal nerve; (6) in the lateral part of the jugular fossa the bone is pierced by the *mastoid canaliculus* for the entrance of the auricular branch of the vagus nerve; (7) behind the jugular fossa the *jugular surface* forms a rough quadrilateral area covered with cartilage in the recent state and articulating with the jugular process of the occipital bone; (8) extending laterally from the carotid

FIG. 352.—A diagrammatic view of the lateral end of the right internal auditory meatus. (Testut.)



canal is the sharp lower border of the tympanic part of the bone; the lateral part of this border splits to ensheath the root of the styloid process and is therefore named the *sheath of the styloid process* (*vagina processus styloidei*); (9) emerging from its sheath the *styloid process*, which is about 2·5 cm. in length, is directed downwards and forwards; (10) between the styloid and mastoid processes the *stylomastoid foramen* forms the lower end of the facial canal and transmits the facial nerve and stylomastoid artery.

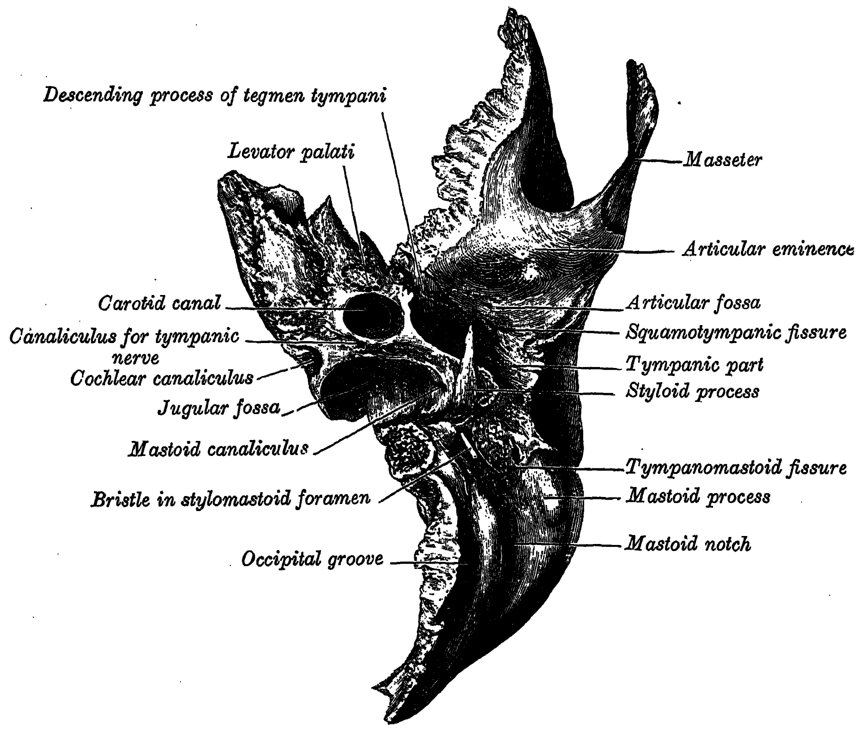
The *superior border*—the longest—is grooved for the superior petrosal sinus and gives attachment to the tentorium cerebelli, except at its medial extremity, where it is crossed by the roots of the trigeminal nerve. The *posterior border* is intermediate in length between the superior and the anterior. Its medial part is marked by a sulcus, which forms, with a corresponding sulcus on the occipital bone, the channel for the inferior petrosal sinus. Behind this there is the *jugular fossa*, which, with the jugular notch on the occipital bone, forms the jugular foramen; it presents a notch for the glossopharyngeal nerve, and either or both of the extremities of the notch may meet the occipital bone and divide the foramen into two, sometimes three, parts. The *anterior border* is divided into two parts—a lateral, joined to the squamous part at the *petrosquamosal suture*; a medial, free, for articulation with the greater wing of the sphenoid bone.

At the angle of junction of the petrous and squamous parts two canals are placed one above the other, and separated by a thin plate of bone. Both canals lead into the tympanic cavity; the upper transmits the tensor tympani; the lower forms the canal of the pharyngotympanic (auditory) tube.

The **tympanic part** of the temporal bone (fig. 353) is a curved plate lying below the squamous part and in front of the mastoid process. Internally, it is fused with the petrous portion, and appears in the angle between it and the squamous part, where it lies below and lateral to the orifice of the pharyngotympanic (auditory) tube. Behind, it fuses with the squamous part and the mastoid process, and forms the anterior boundary of the tympanomastoid fissure. Its *posterior surface* is concave and forms the anterior wall, the floor, and a

part of the posterior wall of the bony external auditory meatus ; at the medial end of this surface there is a narrow furrow, termed the *tympanic sulcus*, for the attachment of the circumference of the tympanic membrane. Its *anterior surface*, quadrilateral and slightly concave, constitutes the posterior wall of the articular fossa and is sometimes in contact with a part of the parotid gland. Its *lateral border* is free and roughened ; it forms a large part of the margin of the opening of the external auditory meatus and gives attachment to the cartilaginous part of the meatus. The lateral part of the *upper border* is fused with the back of the postglenoid tubercle ; its medial part forms the posterior boundary of the petro-tympanic fissure. The *lower border* is sharp ; its lateral part splits to enclose the root of the styloid process and is therefore named the sheath of the styloid process. The central portion of the tympanic part of the temporal bone is thin, and in a considerable percentage of skulls is perforated by a foramen.

FIG. 353.—The left temporal bone. Inferior surface.



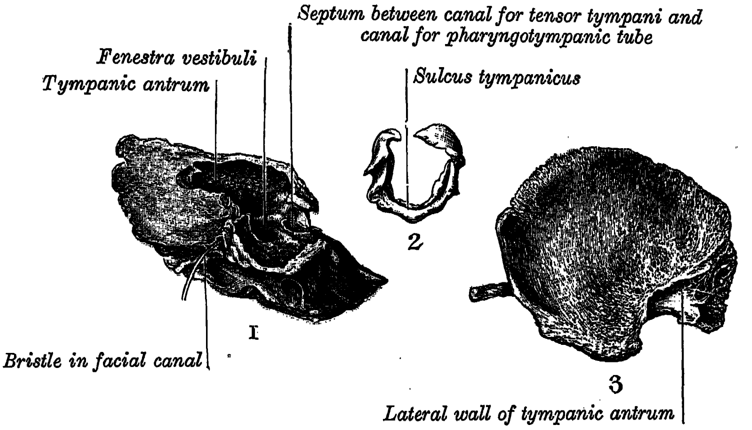
The *external auditory meatus*, which is about 16 mm. long, is directed inwards and slightly forwards and downwards; its floor is convex upwards. On sagittal section the meatus is oval or elliptical in shape with the long axis directed downwards and slightly backwards. Its anterior wall, its floor and the lower part of its posterior wall are formed by the tympanic part of the bone ; its roof and the upper part of its posterior wall by the squamous part. Its inner end is closed in the recent state by the tympanic membrane ; its outer end is bounded above by the posterior root of the zygomatic process, below which the small *suprameatal spine* is sometimes seen at the upper and posterior part of the orifice.

The **styloid process** of the temporal bone, slender, pointed, and averaging about 2·5 cm. in length, projects downwards and forwards, from the under surface of the bone. Its proximal part (tympanohyal) is surrounded by a bony sheath, derived from the tympanic plate and best marked on its anterolateral aspect, while its distal part (stylohyal) gives attachment to certain muscles and ligaments. The styloglossus arises from its anterior aspect close to the tip ; the stylohyoid springs by a delicate little tendon from its posterior surface midway between its tip and its base ; and the stylopharnygeus arises from the medial side close to its base. The stylomandibular ligament is attached to the lateral surface of the process, and the stylohyoid ligament to its tip. The process is covered by the parotid gland, and the facial nerve crosses its base and the external carotid artery its tip, as they lie within the gland. On its deep surface the process is separated from the commencement of the internal jugular vein by the origin of the stylopharyngeus muscle.

Structure.—The structure of the squamous part is like that of the other cranial bones : the mastoid portion is spongy, and the petrous portion dense and hard.

Ossification.—The temporal bone is ossified from eight centres (exclusive of those for the internal ear and the tympanic ossicles)—viz. one each for the squamous and the tympanic part, four for the petrous and mastoid parts, and two for the styloid process. Just before birth the bone consists of three principal parts, viz.: the squamous, the petromastoid part, and the tympanic ring (fig. 354). The *squamous part* is ossified in membrane from a single centre, which appears in the region of the root of the zygomatic process about

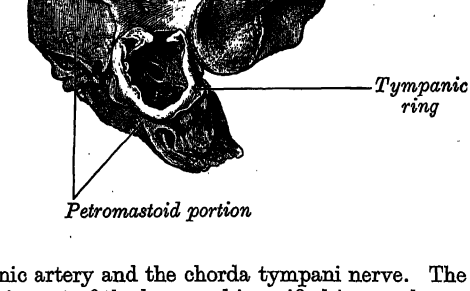
FIG. 354.—The three principal parts of the right temporal bone at birth.



1. External aspect of petromastoid part. 2. Internal aspect of tympanic ring. 3. Internal aspect of squama.

the seventh or eighth week and soon extends in an upward direction. The *petromastoid* part is developed from four centres, which make their appearance in the cartilaginous ear-capsule (p. 130) about the fifth or sixth month of intrauterine life. One (pro-otic) appears in the neighbourhood of the arcuate eminence, spreads in front of and above the internal auditory meatus and extends to the apex of the bone; it covers part of the cochlea, vestibule, superior semicircular duct, and medial wall of the tympanic cavity. A second (opisthotic) appears at the promontory on the medial wall of the tympanic cavity and surrounds the fenestra cochleæ; it forms the floor of the tympanic cavity and vestibule, surrounds the carotid canal, invests the lateral and lower parts of the cochlea, and spreads below the internal auditory meatus. A third (pterotic) forms the roof of the tympanic cavity and antrum; while the fourth (epiotic) appears near the posterior semicircular duct and extends to form the mastoid process (Vrolik). The *tympanic ring* is an incomplete circle, deficient above, the concavity of which is grooved by the tympanic sulcus, for the attachment of the circumference of the tympanic membrane. Two crests, the *superior* and *inferior tympanic crests,* run obliquely downwards and forwards across the anterior part of the inner surface of the ring. Between them an obliquely directed furrow, termed the *sulcus malleolaris,* lodges the anterior process of the malleus, the anterior tympanic artery and the chorda tympani nerve. The tympanic ring expands to form the tympanic part of the bone and is ossified in membrane from a single centre which appears about the third month. The *styloid process* is developed from the cranial end of the cartilage of the second visceral or hyoid arch (p. 99) by two centres: one for the proximal part of the process, termed the tympanohyal, appears before birth; the other, for the distal part of the process, termed the stylohyal, does not appear until after birth. The tympanic ring unites with the squamous part shortly before birth; the petromastoid fuses with the squamous part during the first year, and with the

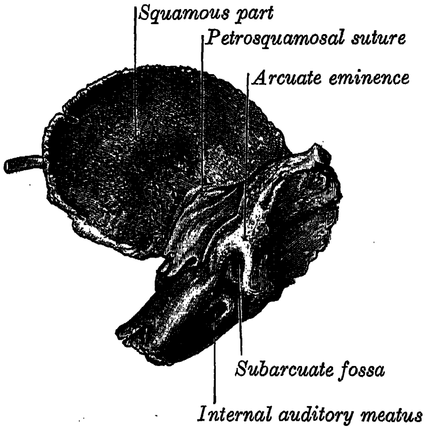
FIG. 355.—The right temporal bone at birth. External aspect.



tympanohyal portion of the styloid process about the same time (figs. 316, 317). The stylohyal does not unite with the rest of the bone until after puberty, and in some skulls never at all.

Subsequently the chief changes in the temporal bone, apart from increase in size, are: (1) The tympanic ring grows laterally and backwards to form the tympanic part of the bone. This growth does not, however, take place at an equal rate all round the ring, but occurs most rapidly on its anterior and posterior portions, and these outgrowths meet and blend, and thus, for a time, there exists in the floor of the meatus a foramen, named the *foramen of Huschke*: this foramen is usually closed about the fifth year, but may persist throughout life. (2) The articular fossa is at first extremely shallow and looks more laterally than downwards; it becomes deeper and is ultimately directed downwards. Its change in direction is accounted for as follows. The portion of the squamous part which forms the fossa lies at first below the level of the zygomatic process and is nearly vertical, but in consequence of the subsequent increase in the width of the base of the skull this portion of the squamous part comes to be directed horizontally inwards, and its surfaces therefore upwards and downwards; the attached portion of the zygomatic process also becomes everted and projects like a shelf at right angles to the squamous. The postero-inferior portion of the squamous part grows downwards behind the tympanic ring and forms the lateral bony wall of the tympanic antrum. (3) The mastoid portion is at first flat, and the stylomastoid foramen and rudimentary styloid process lie immediately behind the tympanic ring. With the development of the mastoid air cells the lateral part of the mastoid portion grows downwards and forwards to form the mastoid process, and the styloid process and stylomastoid foramen come to lie on the under surface of the bone. The descent of the stylomastoid foramen is necessarily accompanied by a corresponding increase in the length of the canal for the facial nerve. It is not until the latter part of the second year that the mastoid process forms a definite elevation on the surface of the skull. (4) The subarcuate fossa on the posterior surface of the petrous portion is gradually filled and almost obliterated.

FIG. 356.—The right temporal bone at birth. Internal aspect.



Applied Anatomy.—The external auditory meatus is relatively as long in the child as in the adult, but in the child the canal is fibro-cartilaginous, whereas in the adult the inner two-thirds of it are osseous. When it is necessary to open the tympanum for suppuration, it is approached through the tympanic antrum. In the child only a thin scale of bone requires to be removed from the suprameatal triangle to open into the tympanic antrum.

The Parietal Bones (Ossa Parietalia)

The parietal bones form, by their union, the sides and the roof of the cranium. Each bone is irregularly quadrilateral in shape, and has two surfaces, four borders, and four angles.

The *external surface* (fig. 357) is convex, smooth, and marked near the centre by a slight elevation, termed the *parietal eminence*. Two curved lines, termed the *superior* and *inferior temporal lines*, cross the middle of the bone, forming an arch which is convex upwards and backwards; the former gives attachment to the temporal fascia; the latter marks the upper limit of the origin of the temporal muscle. The part of the bone above these lines is covered, in the recent condition, with the epicranial aponeurosis (galea aponeurotica); that below the lines forms a part of the temporal fossa. At the posterior part, and close to the upper or sagittal border, the *parietal foramen* transmits a vein from the superior sagittal sinus and, sometimes, a small branch of the occipital artery; the foramen is not constantly present, and its size varies considerably.

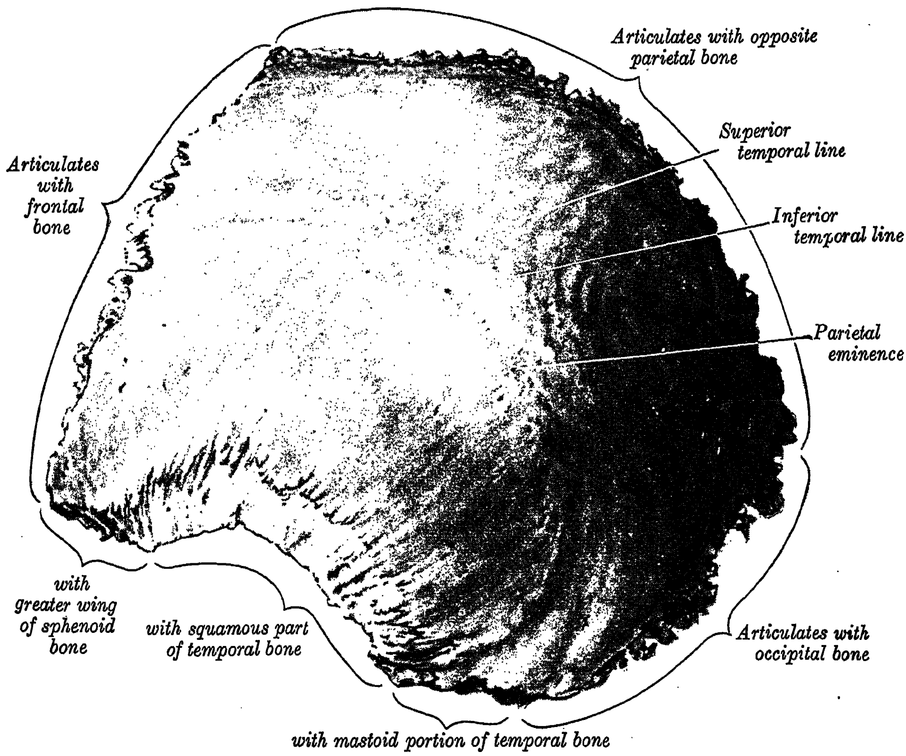
The *internal surface* (fig. 358) is concave; it presents *impressions for the cerebral gyri*, and numerous furrows for the ramifications of the middle meningeal vessels;* these furrows run upwards and backwards from the anterior inferior angle, and from the middle

* Consult articles by F. Wood Jones, *Journal of Anatomy and Physiology*, vol. xlvi., and B. Coen, *Journal of Anatomy and Physiology*, vol. xlviii.

and posterior part of the inferior border. Along the upper or sagittal border there is a shallow groove, which, with that on the opposite parietal bone, forms the *sagittal sulcus* for the superior sagittal sinus; to the edges of this sulcus the falx cerebri is attached. A number of *granular pits*, which lodge arachnoid granulations, mark the bone in the neighbourhood of the sagittal sulcus; they are best marked in the skulls of old persons.

The *upper border*—the longest and thickest—is dentated; it articulates with the corresponding border of the opposite parietal bone to form the sagittal suture. The *lower border* is divided into three parts: of these, the anterior is short, thin and pointed; it is bevelled at the expense of the external surface, and is overlapped by the tip of the greater wing of the sphenoid; the middle portion is arched, bevelled at the expense of the external surface, and overlapped by the squamous part of the temporal bone; the posterior part is short, thick and serrated, and articulates with the mastoid portion of the temporal bone. The *anterior border* is deeply serrated, and bevelled at the expense of the external surface above

FIG. 357.—The left parietal bone. External surface.



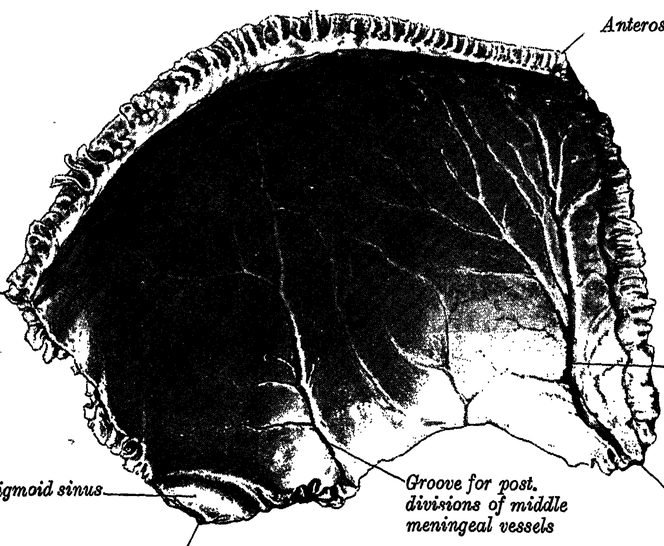
and of the internal below; it articulates with the frontal bone, forming one-half of the coronal suture. The *posterior border*, which is deeply dentated, articulates with the occipital bone, forming one-half of the lambdoid suture.

The *anterior superior angle* is almost a right angle, and corresponds with the *bregma* or point of meeting of the sagittal and coronal sutures. The *anterior inferior angle* is received into the interval between the frontal bone and the greater wing of the sphenoid. Its internal surface is marked by a deep groove—sometimes a canal—for the anterior divisions of the middle meningeal vessels. In some skulls the frontal bone articulates with the squama of the temporal bone, and the parietal bone then fails to reach the greater wing of the sphenoid. The region where these four bones approach closely to one another is termed the *pterion* (p. 251). The *posterior superior angle* is rounded and corresponds with the *lambda* or point of meeting of the sagittal and lambdoid sutures. The *posterior inferior angle* is blunt and articulates with the occipital bone and with the mastoid portion of the temporal bone, the meeting point of the three bones being named the *asterion*. On the internal surface of this angle there is a broad, shallow groove, which lodges the end of the transverse sinus and the commencement of the sigmoid sinus.

At birth there are unossified or membranous intervals in the skull at the angles of the parietal bones; they are named fontanelles (fonticuli) and are described on pp. 326, 327.

Ossification.—The parietal bone is ossified in membrane from two centres, which appear one above the other at the parietal eminence about the seventh week of intrauterine life. These centres unite early, and ossification gradually extends in a radial manner towards the margins of the bone ; the angles are consequently the parts last formed, and it is here that the fontanelles are found. At birth the temporal lines are situated low down ; they reach their permanent position only after the eruption of the molar teeth. Occasionally the parietal bone is divided into upper and lower parts by an anteroposterior suture.

Fig. 358.—The left parietal bone. Internal surface.



The Frontal Bone (Os Frontale)

The **frontal bone** resembles a cockle-shell in shape, and forms the region of the forehead ; on each side it has a horizontal *orbital plate*, which enters into the formation of the roof of the orbital cavity.

The frontal bone has four surfaces, viz.—frontal, right and left temporal and cerebral.

The *frontal surface* (fig. 359) usually exhibits, in the lower part of the median plane, the remains of the *frontal* or *metopic suture* ; in infancy this suture divides the bone into two—a condition which persists in about 9 per cent. of skulls. On each side of the median plane, about 3 cm. above the supra-orbital margin, there is a rounded elevation, termed the *frontal eminence*. These eminences vary in size in different individuals, are occasionally asymmetrical, and are especially prominent in young skulls. Below the frontal eminences, and separated from them by a shallow groove, there are two curved *superciliary arches*, the medial parts of which are prominent and joined to each other by a smooth elevation named the *glabella*. These arches are larger in the male than in the female, and their degree of prominence depends to some extent on the size of the frontal sinuses ; prominent superciliary arches are, however, occasionally associated with small sinuses. Beneath the superciliary arches the curved *supra-orbital margins* form the upper portions of the orbital openings. The lateral two-thirds of each supra-orbital margin are sharp ; the medial one-third is rounded. At the junction of these two parts the *supra-orbital notch*, or *foramen*, is situated ; it transmits the supra-orbital vessels and nerve. Medial to this notch, and present in about 50 per cent. of skulls, is the small *frontal notch* or *foramen*. The supra-orbital margin ends laterally in the *zygomatic process*, which is strong and prominent, and articulates with the zygomatic bone. From this process a line curves upwards and backwards and soon divides into the *superior* and *inferior temporal lines*. It separates the frontal surface from the temporal.

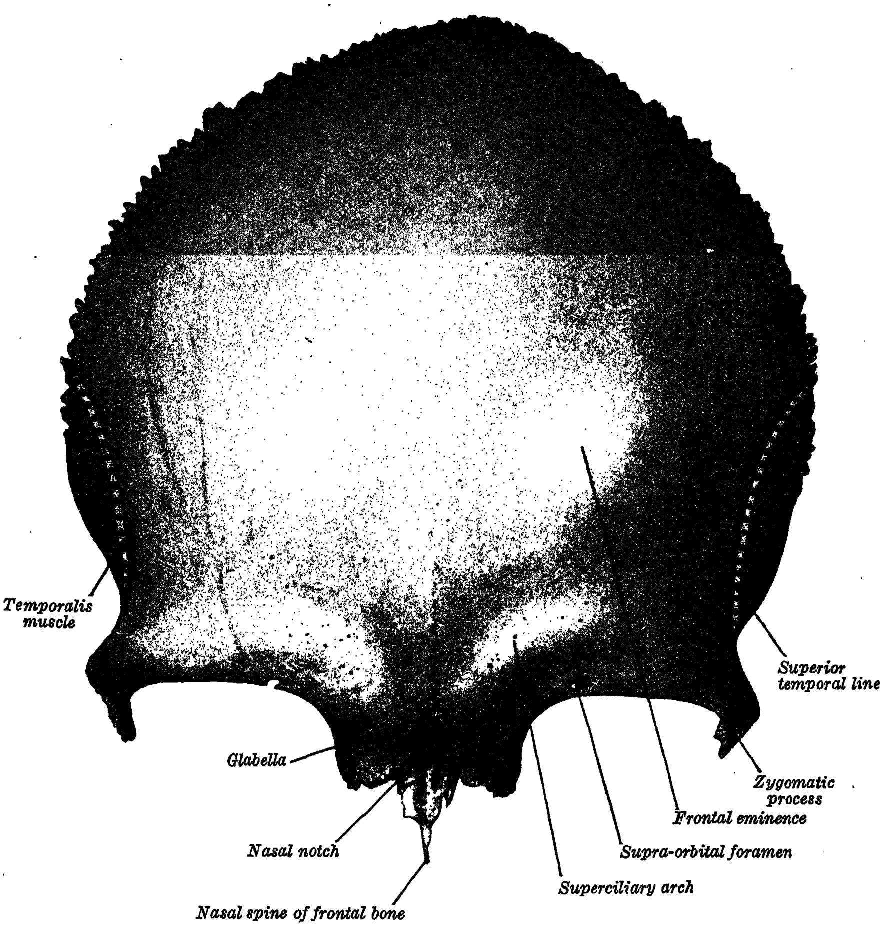
The portion of the bone which projects downwards between the supra-orbital margins is named the *nasal part*. It presents an uneven interval, sometimes termed the *nasal notch*, which articulates on each side of the median plane with the nasal bone, and lateral to this with the frontal process of the maxilla and with the lacrimal bone. From the centre of the notch the *nasal part* projects downwards and forwards behind the nasal bones (fig. 330) and

frontal processes of the maxillæ, and supports the bridge of the nose. The nasal part ends below in a sharp *nasal spine,* and on each side of this there is a small grooved surface which forms a part of the roof of the corresponding nasal cavity. The nasal spine forms a part of the septum of the nose; in front it articulates with the crest of the nasal bones, behind with the perpendicular plate of the ethmoid bone (fig. 328).

The *temporal surface,* below and behind the temporal lines, forms the anterior part of the temporal fossa and gives origin to a part of the temporal muscle.

The *cerebral surface* (fig. 360) of the frontal bone is concave. In the upper part of the median plane it is marked by a vertical groove, termed the *sagittal sulcus,* the edges of which unite below to form the *frontal crest*; the sulcus lodges the anterior part of the

Fig. 359.—The frontal bone. External surface.



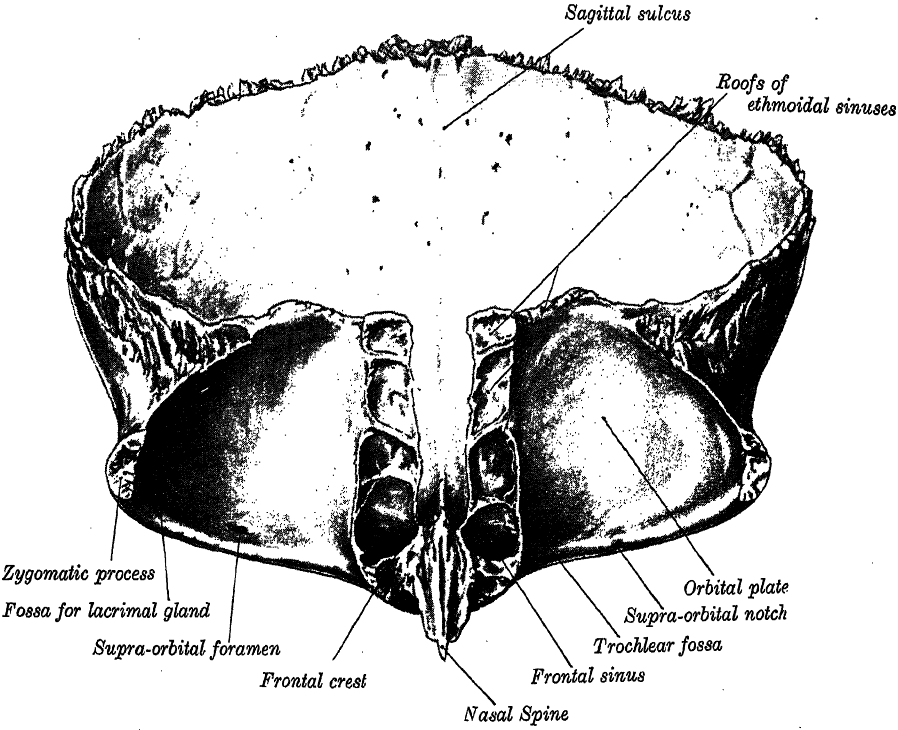
superior sagittal sinus, while to its margins and to the frontal crest the anterior part of the falx cerebri is attached. The crest ends below in a small notch, which is converted into the *foramen cæcum* by articulation with the ethmoid bone. The foramen cæcum varies in size in different skulls, and is rarely pervious; in these rare cases, it transmits a vein from the nose to the superior sagittal sinus. On each side of the median plane the surface is marked by *impressions for the cerebral gyri,* and minute furrows for meningeal vessels. Several small, irregular fossæ may be seen on each side of the sagittal sulcus, for the reception of arachnoid granulations. They are termed *granular pits.*

The *parietal margin* is thick, strongly serrated, bevelled at the expense of the cerebral surface above, where it rests upon the parietal bones, and at the expense of the temporal surface on each side, where it receives the lateral pressure of the parietal bones; it is continued below into a triangular, rough surface, for articulation with the greater wing of the sphenoid bone.

The orbital plates of the frontal bone consist of two thin triangular lamellæ, which form the vaults of the orbits, and are separated from each other by a wide gap named the *ethmoidal notch.*

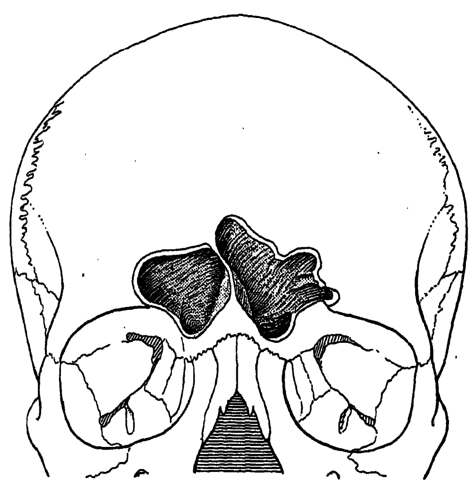
The *orbital surface* (fig. 360) of each orbital plate is smooth and concave, and presents, in its anterolateral part, a shallow depression which lodges the lacrimal gland and consequently is termed the *fossa for the lacrimal gland*; below and behind the medial end of the

FIG. 360.—The frontal bone. Viewed from below.



supra-orbital margin, about midway between the supra-orbital notch and the fronto-lacrimal suture, there is a small depression or spine [the *fossa vel spina trochlearis*], for the attachment of the fibrocartilaginous pulley of the superior oblique muscle. The *cerebral*

FIG. 361.—Frontal sinuses. Anterior aspect. The left sinus is larger than the right and the septum between them is obliquely placed.

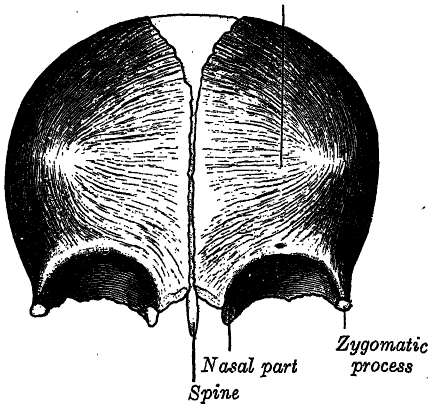


surface is convex, and marked by impressions for the gyri on the inferior surface of the frontal lobe of the brain, and by faint grooves for the meningeal branches of the ethmoidal vessels.

The *ethmoidal notch* (fig. 360) separates the two orbital plates; it is quadrilateral in outline and is filled, in the articulated skull, by the cribriform plate of the ethmoid bone. On the margins of the notch portions of several air-sinuses are present: they complete the ethmoidal sinuses when the ethmoid bone is in position. Two transverse grooves cross each margin of the notch; they are converted into the *anterior* and *posterior ethmoidal canals* by the ethmoid bone, and open on the medial wall of the orbit; they transmit the anterior and posterior ethmoidal nerves and vessels.

The openings of the *frontal sinuses* (fig. 360) are situated in front of the ethmoidal notch, and lateral to the nasal spine. These sinuses are two irregular cavities, which extend backwards, upwards, and laterally for a variable distance between the tables of the frontal bone; they are separated from each other by a thin bony septum, which is often deflected to one or other side of the median plane, with the result that the sinuses are seldom symmetrical. Rudimentary at birth, the frontal sinuses are usually fairly well-developed between the seventh and eighth years, but reach their full size only after puberty. They vary in size in different persons and are larger in men than in women.* Occasionally they extend backwards in the roofs of the orbital cavities as far as the optic foramina. Each communicates with the middle meatus of the corresponding nasal cavity by means of a passage called the *fronto-nasal duct*. (Pl. I.)

FIG. 362.—The frontal bone at birth. External aspect.



The *posterior borders of the orbital plates* are thin and serrated, and articulate with the lesser wings of the sphenoid; the lateral part of each usually appears in the middle cranial fossa between the greater and lesser wings of the sphenoid bone.

Structure.—The frontal bone is thick and consists of spongy substance contained between two compact laminæ; the spongy substance is absent in the regions occupied by the frontal sinuses. The orbital plate, composed entirely of compact bone, is thin and translucent in its posterior two-thirds.

Ossification (fig. 362).—The frontal bone is ossified in membrane from two primary centres which appear in the seventh or eighth week of intrauterine life, one above each supra-orbital margin. From each of these centres ossification extends upwards to form the corresponding half of the bone, and backwards to form the orbital plate. The nasal spine is ossified from two secondary centres, one on each side of the median plane; secondary centres also appear in the nasal parts and zygomatic processes. At birth the bone consists of two pieces separated by the frontal suture, but union of the pieces begins in the second year, and the frontal suture is usually obliterated, except at its lower part, by the eighth year.

THE ETHMOID BONE (OS ETHMOIDALE)

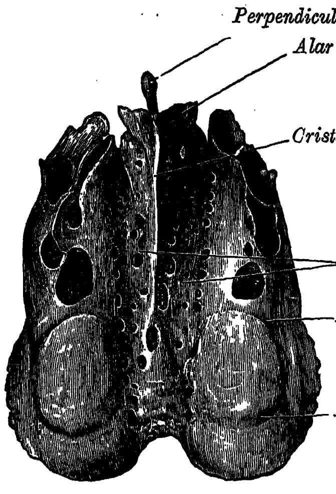
The **ethmoid bone** is cuboidal in shape, and exceedingly light; it is situated at the anterior part of the base of the cranium, and assists in forming the medial walls of the orbits, the septum of the nose, and the roof and lateral walls of the nasal cavity. It consists of four parts: a horizontal, perforated plate named the cribriform plate, a perpendicular plate and two lateral masses named the labyrinths.

The **cribriform plate** of the ethmoid (fig. 363) occupies the ethmoidal notch of the frontal bone and forms a part of the roof of the nasal cavity. A thick, smooth, triangular process, called the *crista galli* from its resemblance to a cock's comb, projects upwards from this lamina in the median plane. Its posterior border, long, thin, and curved, gives attachment to the falx cerebri. Its anterior border, short and thick, articulates with the frontal bone by two small projecting *alæ* which complete the foramen cæcum. Its sides are smooth, and sometimes bulging owing to the presence of a small air-sinus in the interior. On each side of the crista galli the cribriform plate is narrow and depressed; it supports the gyrus rectus and presents numerous foramina for the passage of the olfactory nerves. The foramina in its middle part are small and transmit the nerves from the mucous membrane of the roof

* Logan Turner (*op. cit.*) gives the following measurements for an adult sinus of average size: height, 3·16 cm.; breadth, 2·58 cm.; depth from before backwards, 1·8 cm. Onodi (*op. cit.*) states that in infants of from one to twelve months the height of the frontal sinus varies from 3·5 mm. to 8 mm., and its width from 2 mm. to 6 mm., and that in the eighth year of life the height is from 14 mm. to 17 mm., and the width from 7 mm. to 9 mm.

of the nasal cavity; those in the medial and lateral parts are larger—the former transmit the nerves from the mucous membrane on the upper part of the nasal septum, the latter the nerves from the mucous membrane on the superior nasal concha. At the front part of the cribriform plate, on each side of the crista galli, there is a small slit-like fissure, which is occupied by a process of dura mater. The foramen which transmits the anterior ethmoidal nerve to the nasal cavity is placed lateral to the anterior end of the fissure, and from it a groove runs backwards to the orifice of the anterior ethmoidal canal.

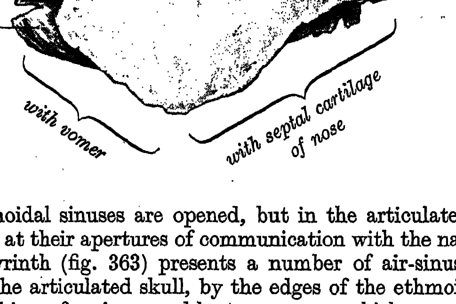
FIG. 363.—The ethmoid bone. Superior aspect.



The **perpendicular plate** of the ethmoid (figs. 364, 365), is thin, flat and quadrilateral in form. It descends from the under surface of the cribriform plate and forms the upper part of the nasal septum; it is generally deflected a little to one or other side. The *anterior border* articulates with the nasal spine of the frontal bone and the crest of the nasal bones. The *posterior border* articulates with the sphenoidal crest above and with the vomer below. The *superior border* is attached to the cribriform plate. The *inferior border* is thick, and serves for the attachment of the septal cartilage of the nose. The surfaces of the lamina are smooth, except above, where numerous grooves and canals are seen; these lead to the medial foramina in the cribriform plate and lodge filaments of the olfactory nerves.

Each **labyrinth** of the ethmoid bone consists of a number of thin-walled *ethmoidal sinuses,* arranged in three groups—*anterior, middle,* and *posterior*—and interposed between two vertical plates of bone; the lateral or *orbital plate* forms part of the medial wall of the orbit, the medial plate, part of the lateral wall of the nasal cavity.* In the disarticulated bone many of these ethmoidal sinuses are opened, but in the articulated skull they are everywhere closed, except at their apertures of communication with the nasal cavity. The *upper surface* of the labyrinth (fig. 363) presents a number of air-sinuses, the walls of which are completed, in the articulated skull, by the edges of the ethmoidal notch of the frontal bone (fig. 360). This surface is crossed by two grooves which are converted into the *anterior* and *posterior ethmoidal canals* by articulation with the frontal bone. On the *posterior surface* of each labyrinth (fig. 365) large air-sinuses are visible, and their walls

FIG. 364.—The perpendicular plate of the ethmoid bone. Right lateral aspect. Shown after removal of the right labyrinth.

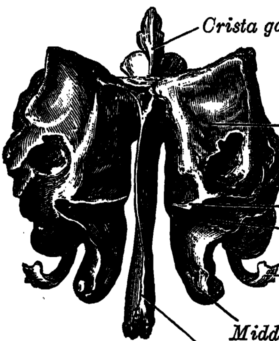


* Some anatomists divide the ethmoidal sinuses into two groups, an *anterior,* comprising those which open into the middle meatus, and a *posterior,* those which open into the superior meatus of the nose.

are completed by the sphenoidal concha and the orbital process of the palatine bone. The *lateral surface* (fig. 366) consists of a thin, smooth, oblong plate, named the *orbital plate,* which covers the middle and posterior ethmoidal sinuses and forms a large part of the medial wall of the orbit; it articulates above with the orbital plate of the frontal bone, below with the maxilla and the orbital process of the palatine bone, in front with the lacrimal bone, and behind with the sphenoid bone (fig. 314).

A few sinuses lie in front of the orbital plate and their walls are completed by the lacrimal bone and the frontal process of the maxilla. A curved lamina, termed the *uncinate process,* which is subject to considerable variation in size, projects downwards and backwards from

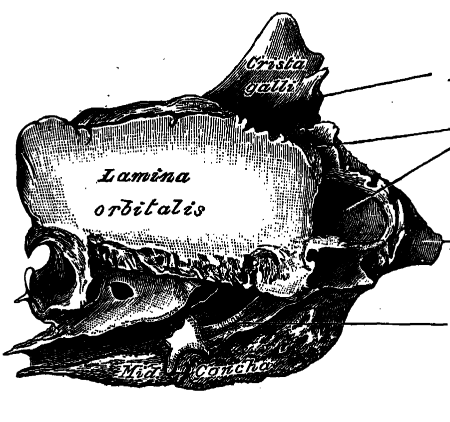
FIG. 365.—The ethmoid bone. Posterior aspect.



this part of the labyrinth; it forms a small part of the medial wall of the maxillary sinus (fig. 314), and articulates with the ethmoidal process of the inferior nasal concha. The upper edge of this process is free and forms the medial boundary of the hiatus semilunaris.

The *medial surface* of the labyrinth (fig. 367) forms part of the lateral wall of the corresponding half of the nasal cavity; it consists of a thin lamella, which descends from the under surface of the cribriform plate and ends in a free, convoluted portion, named the *middle nasal concha.* The upper part of the medial surface is marked by numerous grooves, directed nearly vertically downwards; they lodge branches of the olfactory nerves. The posterior part of the medial surface is subdivided by a narrow, oblique fissure, termed the

FIG. 366.—The ethmoid bone. Right lateral aspect.

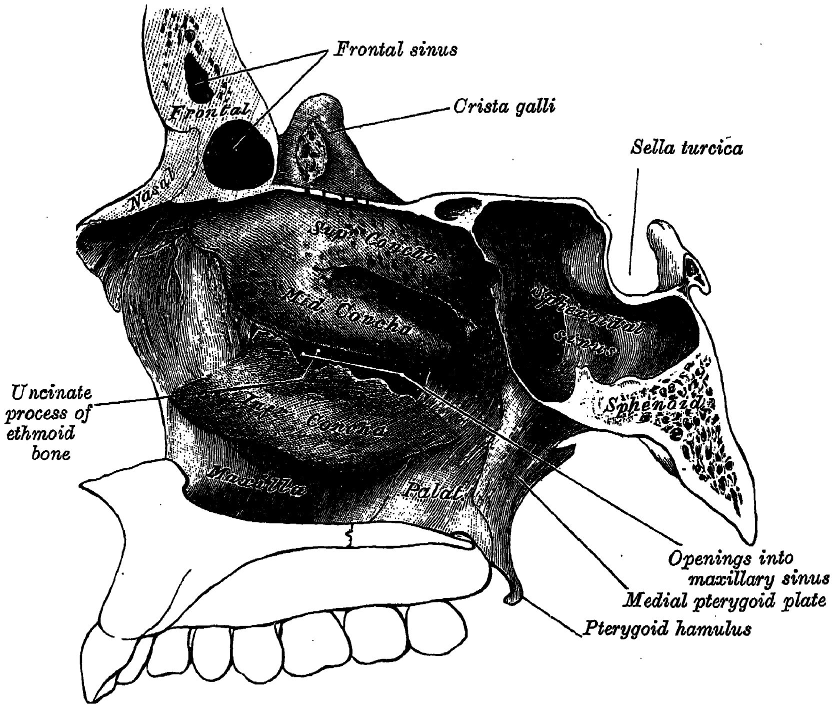


superior meatus of the nose, which is bounded above by a thin, curved plate, named the *superior nasal concha*; the posterior ethmoidal sinuses open into this meatus. Below and in front of the superior meatus the convex surface of the middle nasal concha extends along the whole length of the medial surface of the labyrinth. Its lower margin is free and thick, while its lateral surface is concave and assists in forming the *middle meatus* of the nose. The middle ethmoidal sinuses produce a rounded swelling, named the *bulla ethmoidalis,* on the lateral wall of the middle meatus (fig. 368); on the bulla, or immediately above it, these sinuses open into the meatus. A curved passage, named the *infundibulum,*

extends upwards and forwards from the middle meatus; it communicates with the anterior ethmoidal sinuses, and in rather more than 50 per cent. of skulls is continued upwards as the frontonasal duct into the frontal sinus.

Ossification.—The ethmoid bone is ossified in the cartilaginous nasal capsule from three centres; one for the perpendicular plate, and one for each labyrinth.

FIG. 367.—The lateral wall of the right half of the nasal cavity, showing the ethmoid bone (coloured red) and the inferior nasal concha (coloured blue) in position.



The centre for each labyrinth appears in the region of the orbital plate between the fourth and fifth months of intrauterine life, and extends into the conchæ. At birth, the two labyrinths, which are small and ill-developed, are partially ossified, but the rest of the bone is cartilaginous. During the first year after birth, the perpendicular plate and crista galli begin to ossify from a single centre, and they are joined to the labyrinths about the beginning of the second year. The cribriform plate is ossified partly from the perpendicular plate and partly from the labyrinths. The ethmoidal sinuses begin to develop during intrauterine life, and in the new-born infant have the form of narrow pouches.

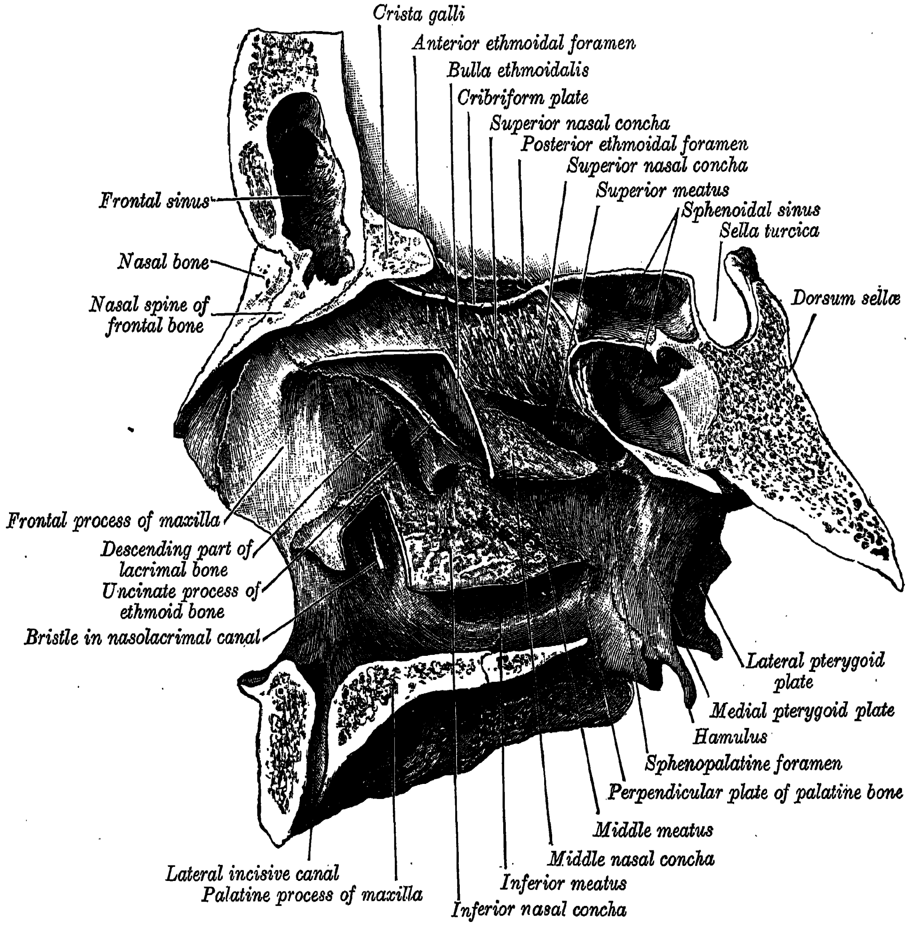
The Inferior Nasal Conchæ (Conchæ Nasales Inferiores)

The **inferior nasal conchæ** are curved laminæ which lie horizontally in the lateral walls of the nasal cavity (fig. 367). Each bone has two surfaces, two borders, and two ends.

The *medial surface* (fig. 369) is convex, perforated by numerous apertures, and traversed by longitudinal grooves for the lodgement of vessels. The *lateral surface* is concave (fig. 370), and forms part of the inferior meatus of the nasal cavity. The *superior border* is thin and irregular, and may be divided into three portions: of these, the anterior articulates with the conchal crest of the maxilla, and the posterior with the conchal crest of the palatine bone. The middle portion presents three processes, which vary in size and form. Of these, the *lacrimal process* is small and pointed and is situated at the junction of the anterior one-fourth with the posterior three-fourths of the bone: it articulates, by its apex, with a descending process from the lacrimal bone (fig. 368) and, by its margins, with the edges of the nasolacrimal groove on the medial surface of the body of the maxilla; it thus assists in forming the canal for the nasolacrimal duct. Behind this process a thin plate, named the *ethmoidal process*, ascends to join the uncinate process of the ethmoid (fig. 368). From the middle part of the superior border a thin lamella, termed the *maxillary process*, curves

downwards and laterally; it articulates with the maxilla and the maxillary process of the palatine bone, and forms a part of the medial wall of the maxillary sinus (fig. 383). The

FIG. 368.—The lateral wall of the right half of the nasal cavity, after removal of parts of the middle and inferior nasal conchæ.



inferior border is free, thick, and spongy in structure, more especially in the middle of the bone. Both *ends* are more or less pointed, the posterior being the more tapered.

Ossification.—The inferior nasal concha is ossified from one centre; this appears about

FIG. 369.—The right inferior nasal concha. Medial surface.

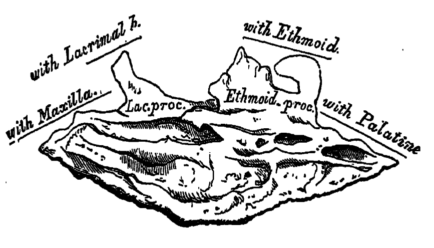
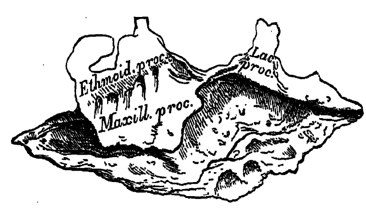


FIG. 370.—The right inferior nasal concha. Lateral surface.



the fifth month of intrauterine life in the incurved lower border of the lateral wall of the cartilaginous nasal capsule. It is detached from the remainder of the nasal capsule during ossification.

The Lacrimal Bones (Ossa Lacrimalia)

The **lacrimal bones**, which are the smallest and most fragile of the cranial bones, are situated at the front parts of the medial walls of the orbits (figs. 373, 383). Each lacrimal bone has two surfaces and four borders. The *lateral* or *orbital surface* (fig. 371) is divided by a vertical ridge, termed the *crest of the lacrimal bone*. In front of this crest there is a vertical groove, the anterior border of which articulates with the posterior border of the frontal process of the maxilla to complete the *lacrimal groove* for the lodgment of the lacrimal sac. The medial wall of the groove is prolonged downwards as a descending process (fig. 372) to assist in forming the bony canal for the nasolacrimal duct by articulating with the lips of the naso-lacrimal groove of the maxilla, and with the lacrimal process of the inferior nasal concha. The portion behind the crest is smooth and forms a part of the medial wall of the orbit. The crest, with a part of the orbital surface immediately posterior to it, gives origin to the lacrimal part of the orbicularis oculi muscle. The crest ends below in a small hook, termed the *lacrimal hamulus*, which articulates with the maxilla and completes the upper orifice of the bony canal for the nasolacrimal duct; the lacrimal hamulus sometimes exists as a separate piece, and is then called the *lesser lacrimal bone*. On the *medial* or *nasal surface* a vertical furrow corresponds to the crest on the lateral surface. The area in front of this furrow forms part of the middle meatus of the nose; that behind the furrow articulates with the ethmoid bone and completes some of the anterior ethmoidal sinuses. The *anterior border* of the lacrimal bone articulates with the frontal process of the maxilla: the *posterior border* with the orbital plate of the ethmoid; the *superior border* with the frontal bone. The posterior part of the *inferior border* articulates with the orbital surface of the maxilla.

Fig. 371.—The left lacrimal bone. Lateral aspect. (Enlarged.)

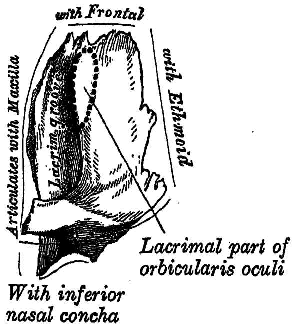
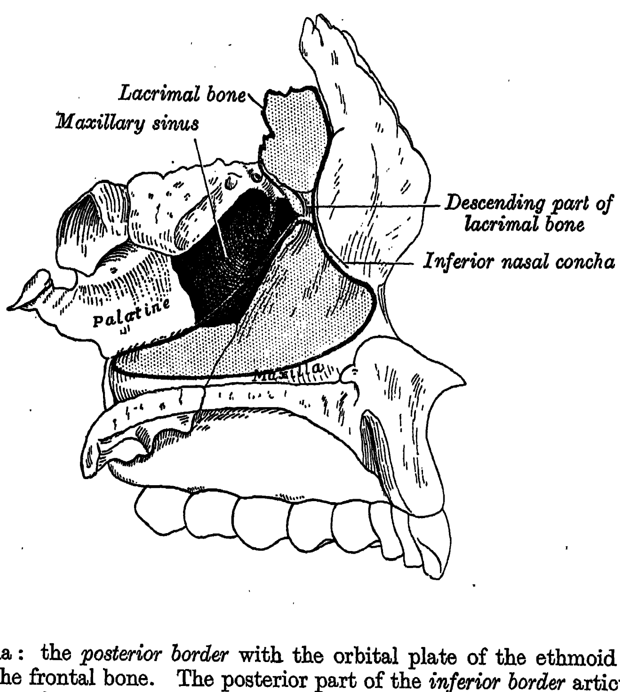


Fig. 372.—A sketch showing how the medial wall of the nasolacrimal canal is completed by the articulation of the descending process of the lacrimal bone with the lacrimal process of the inferior nasal concha. (After Whitnall.)

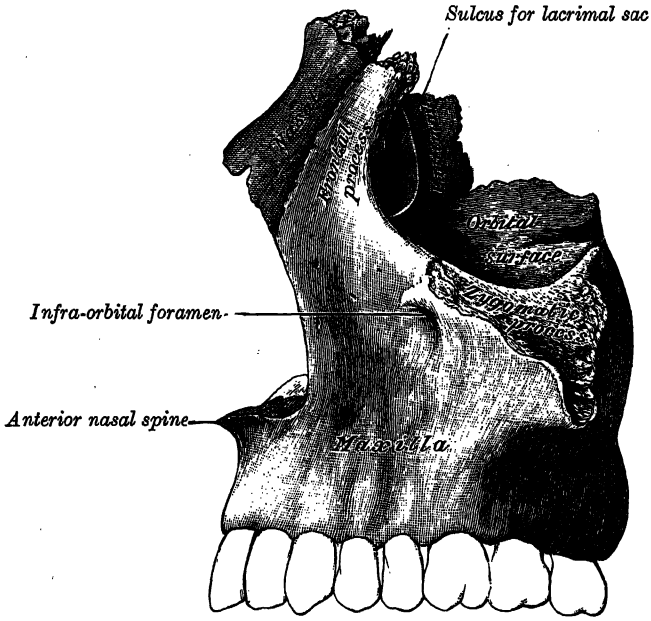


Ossification.—The lacrimal bone is ossified from one centre, which appears about the twelfth week of intrauterine life in the membrane covering the cartilaginous nasal capsule.

THE NASAL BONES (OSSA NASALIA)

The **nasal bones** are two small oblong bones, varying in size and form in different individuals; they are placed side by side between the frontal processes of the maxillæ, and form, by their junction, 'the bridge' of the nose (figs. 311, 373).

FIG. 373.—The articulation of the nasal and lacrimal bones with the maxilla. Left lateral aspect.



Each nasal bone has two surfaces and four borders. The *external surface* (fig. 374) is concavo-convex from above downwards, and convex from side to side; it is covered by the procerus and compressor naris, and is perforated near its centre by a foramen for the transmission of a small vein. The *internal surface* (fig. 375) is concave from side to side, and is

FIG. 374.—The left nasal bone. External surface.

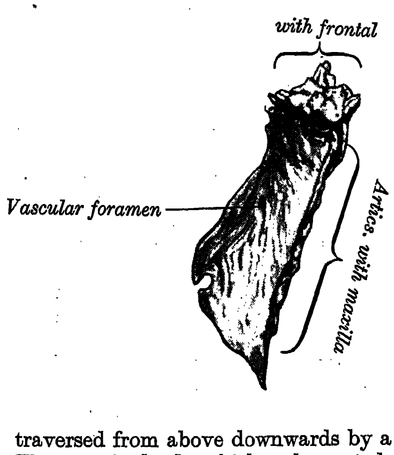
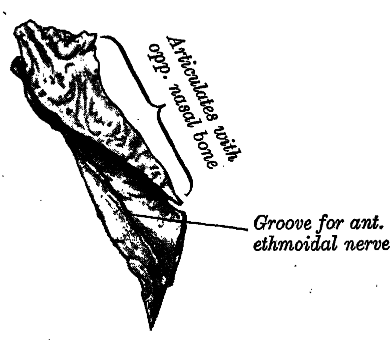


FIG. 375.—The left nasal bone. Internal surface.



traversed from above downwards by a groove which lodges the anterior ethmoidal nerve. The *superior border*, thick and serrated, articulates with the nasal notch of the frontal bone. The *inferior border*, thin and notched, gives attachment to the lateral cartilage of the nose. The *lateral border* articulates with the frontal process of the maxilla. The *medial border*, thicker above than below, articulates with the opposite nasal bone and is prolonged behind

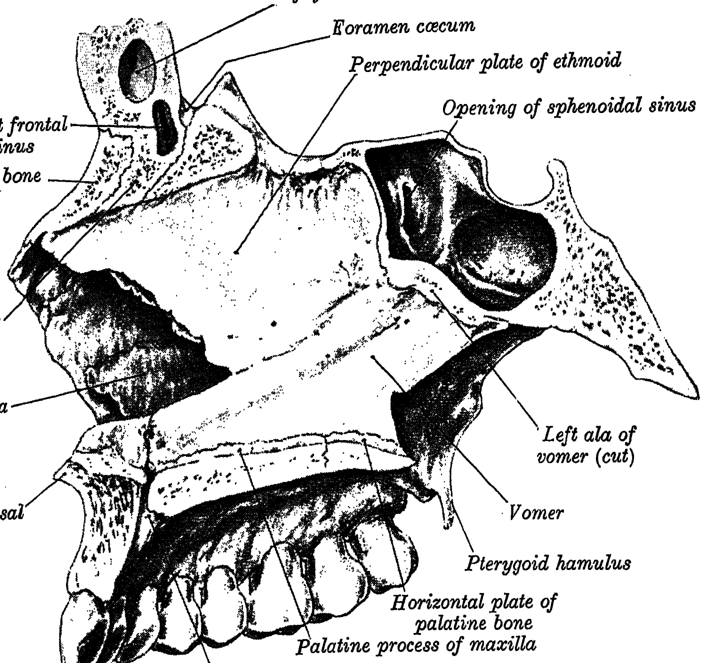
into a vertical crest, which forms a small part of the septum of the nose, and articulates, from above downwards, with the nasal spine of the frontal, the perpendicular plate of the ethmoid, and the cartilage of the septum of the nose.

Ossification.—The nasal bone is ossified from one centre, which appears at the beginning of the third month of intrauterine life in the membrane overlying the anterior part of the cartilaginous nasal capsule.

The Vomer

The **vomer** is thin, flat bone, almost quadrilateral in shape; it forms the hinder and lower part of the septum of the nose (fig. 376) and has two surfaces and four borders. Each *surface* (fig. 377) is marked by small furrows for blood-vessels, and is traversed by a groove which runs obliquely downwards and forwards, and lodges the corresponding long spheno-palatine nerve and vessels. The *superior border* is the thickest, and presents a deep furrow, bounded on each side by a projecting *ala*: the furrow receives the rostrum of the sphenoid; the alæ articulate with the sphenoidal conchæ, the sphenoidal processes of the palatine

Fig. 376.—The medial wall of the left half of the nasal cavity, showing the vomer *in situ*.



bones and the vaginal processes of the medial pterygoid plates. When the edge of the ala occupies the interval between the body of the sphenoid and the vaginal process, its lower surface takes part in the formation of the vomerovaginal canal (p. 260). The *inferior border* articulates with the nasal crest formed by the maxillæ and palatine bones. The *anterior border* is the longest; its upper half articulates with the perpendicular plate of the ethmoid, its lower is cleft for the reception of the inferior margin of the cartilage of the septum of the nose. The *posterior border* is free, concave, and separates the posterior nasal apertures; it is thick and bifid above, thin below. The anterior end of the vomer articulates with the posterior margin of the incisor crest of the maxillæ and projects downwards between the incisive canals.

Ossification.—At an early period the septum of the nose consists of a plate of cartilage. The superior part of this cartilage is ossified to form the perpendicular plate of the ethmoid; its antero-inferior portion persists as the septal cartilage, whilst the vomer is ossified in the membrane covering its postero-inferior part. About the eighth week of intrauterine life two centres of ossification, one on each side of the median plane, appear in this part of the membrane, medial to and a little behind the paraseptal cartilages (p. 90). About the third month these centres unite below the cartilage, and thus a deep groove is formed (fig. 378) in which the cartilage of the septum of the nose is lodged. As growth proceeds, the union of the bony

lamellæ extends upwards and forwards and at the same time the intervening plate of cartilage undergoes absorption. By the age of puberty the lamellæ are almost completely united, but evidence of the bilaminar origin of the bone is seen in the everted alæ of its upper

FIG. 377.—The vomer. Left lateral aspect.

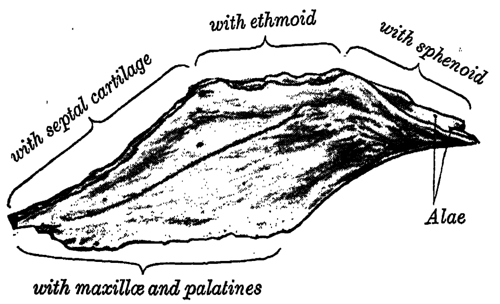


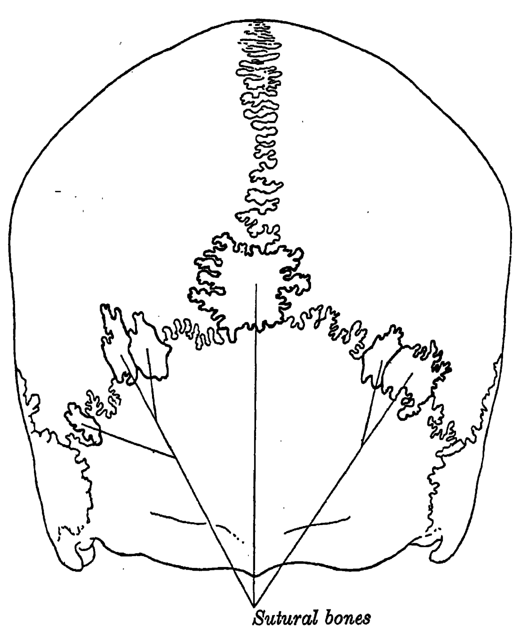
FIG. 378.—The vomer of an infant.

border and the groove on its anterior margin. Up to a certain stage the vomer is entirely derived from membrane, but 'it becomes added to by the ossification of the hinder end of the anterior paraseptal cartilage.' *

THE SUTURAL BONES (OSSA SUTURARUM)

In addition to the usual centres of ossification of the cranial bones, others may occur in the course of the sutures, giving rise to irregular, isolated, *sutural bones* (fig. 379). They occur most frequently in the course of the lambdoid suture, but are occasionally seen at the

FIG. 379.—A sketch showing sutural bones in the lambdoid and sagittal sutures.



fontanelles, especially the posterior. One—the *pterion ossicle*—sometimes exists between the anterior inferior angle of the parietal bone and the greater wing of the sphenoid bone. These bones vary much in size, but have a tendency to be more or less symmetrical on the two sides of the skull. Their number is generally limited to two or three; but more than a hundred have been found in the skull of a hydrocephalic subject.

* E. Fawcett, *Journal of Anatomy and Physiology*, vol. xlv.

THE FACIAL BONES (OSSA FACIEI)

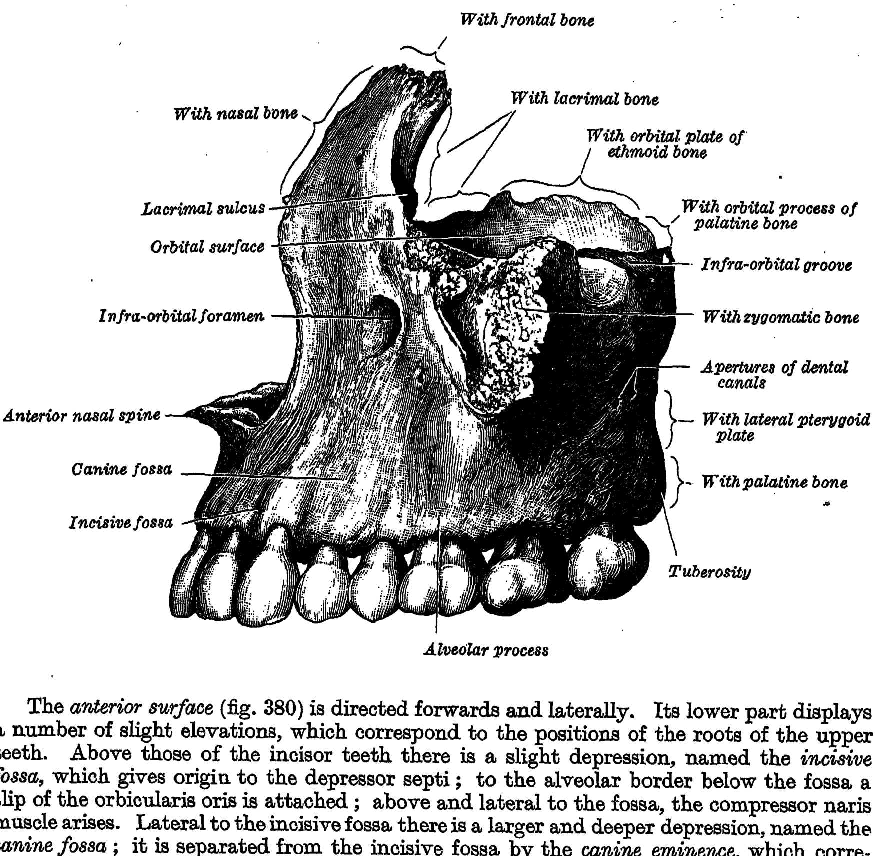
The Maxillæ

The maxillæ are the largest bones of the face, excepting the mandible, and by their union form the whole of the upper jaw (fig. 311). Each assists in completing the roof of the mouth, the floor and lateral wall of the nasal cavity, and the floor of the orbit; it also enters into the formation of the infratemporal and pterygopalatine fossæ, and the inferior orbital and pterygomaxillary fissures.

Each maxilla consists of a body and four processes—zygomatic, frontal, alveolar, and palatine.

The body of the maxilla is pyramidal in shape. It has four surfaces—anterior, posterior, orbital, and nasal—and encloses a large cavity, termed the maxillary sinus.

Fig. 380.—The left maxilla. Lateral aspect.



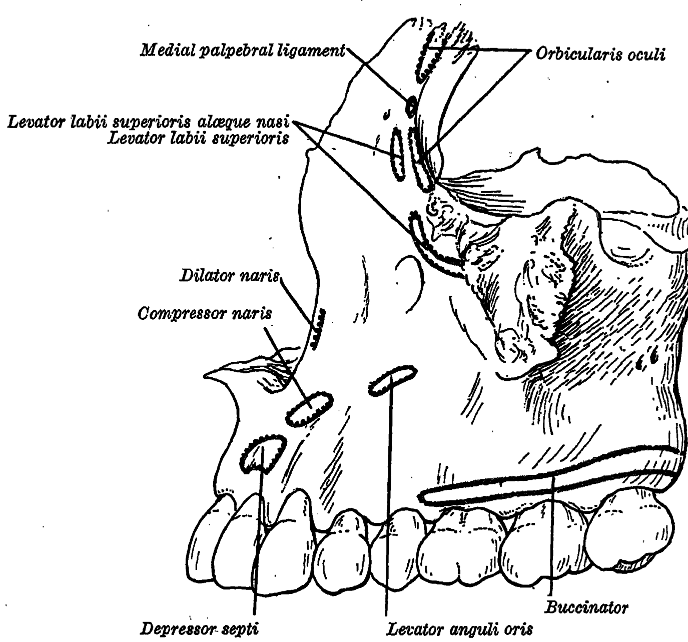
The *anterior surface* (fig. 380) is directed forwards and laterally. Its lower part displays a number of slight elevations, which correspond to the positions of the roots of the upper teeth. Above those of the incisor teeth there is a slight depression, named the *incisive fossa*, which gives origin to the depressor septi; to the alveolar border below the fossa a slip of the orbicularis oris is attached; above and lateral to the fossa, the compressor naris muscle arises. Lateral to the incisive fossa there is a larger and deeper depression, named the *canine fossa*; it is separated from the incisive fossa by the *canine eminence*, which corresponds to the socket of the canine tooth; the fossa gives origin to the levator anguli oris (caninus) muscle. Above the canine fossa the *infra-orbital foramen* marks the anterior end of the infra-orbital canal; it transmits the infra-orbital vessels and nerve. Above the foramen a sharp border marks the junction of the anterior and orbital surfaces. This border forms a small part of the circumference of the orbital opening, and gives origin to the levator labii superioris (infra-orbital head of the quadratus labii superioris). On the medial side, the anterior surface is limited by a deep concavity, termed the *nasal notch*; the margin of the notch gives attachment to the dilator naris and ends below in a pointed process which, with the corresponding process of the opposite maxilla, forms the *anterior nasal spine*.

The *posterior surface* (*infratemporal surface*) (fig. 380) is convex, directed backwards and laterally, and forms the anterior wall of the infratemporal fossa. It is separated from the anterior surface by the zygomatic process and by a ridge which runs upwards to that process from the socket of the first molar tooth. It presents near its centre the apertures of

two or three *dental canals*, which transmit the posterior superior dental vessels and nerves. At the lower part of this surface there is a round eminence, termed the *maxillary tuberosity*, which is rough for articulation with the tubercle (pyramidal process) of the palatine bone (fig. 380); it gives origin to a few fibres of the medial pterygoid muscle and, in some cases, articulates with the lateral pterygoid plate of the sphenoid bone. Above this a smooth surface forms the anterior boundary of the pterygopalatine fossa and is grooved for the maxillary nerve; the groove for this nerve is directed laterally and slightly upwards and is continuous with the infra-orbital groove on the orbital surface.

The *orbital surface* (fig. 380) is smooth and triangular, and forms the greater part of the floor of the orbit. Its *medial border* presents anteriorly a notch, termed the *lacrimal notch*, behind which it articulates from before backwards with the lacrimal bone, the orbital plate of the ethmoid, and the orbital process of the palatine bone (fig. 383). Its *posterior border* is smooth and rounded; it forms the greater part of the anterior margin of the inferior orbital fissure, and its middle part is notched by the commencement of the infra-orbital

FIG. 381.—Outline of left maxilla, showing muscular attachments.



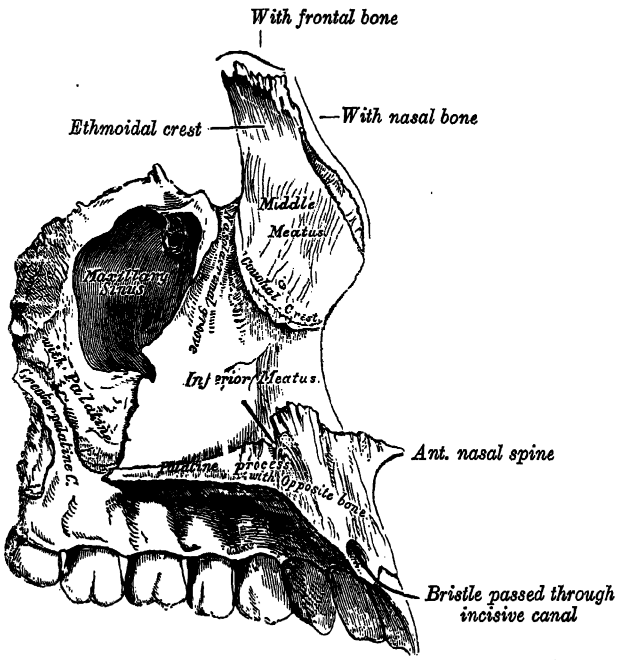
groove. The *anterior border* forms a small part of the circumference of the orbital opening and is continuous medially with the lacrimal crest on the frontal process (p. 314). The *infra-orbital groove*, for the passage of the infra-orbital vessels and nerve, begins at the middle of the posterior border, where it is continuous with the groove near the upper edge of the posterior surface; it passes forwards and ends in the *infra-orbital canal*, which opens on the anterior surface of the bone just below the infra-orbital margin. At the medial and front part of the orbital surface, and lateral to the lacrimal groove, the origin of the inferior oblique muscle of the eyeball may be marked by a small depression.

The *nasal surface* (fig. 382) presents in its upper and posterior part a large, irregular opening, termed the *maxillary hiatus*, which leads into the maxillary sinus. At the upper border of this aperture there are some broken air-sinuses, which, in the articulated skull, are closed by the ethmoid and lacrimal bones. Below the maxillary hiatus a smooth concave surface forms part of the inferior meatus of the nasal cavity, and behind it there is a rough surface for articulation with the perpendicular plate of the palatine bone; this rough surface is traversed by a groove, which begins near the middle of the posterior border, runs obliquely downwards and forwards, and is converted into the *greater palatine canal* (*pterygopalatine canal*) by the perpendicular plate of the palatine bone. In front of the maxillary hiatus a deep groove, which is continuous above with the lacrimal groove (p. 312), constitutes about two-thirds of the circumference of the nasolacrimal canal, the remaining one-third being formed by the descending part of the lacrimal bone and the lacrimal process of the inferior nasal concha (fig. 372); this canal opens into the inferior meatus of the nose (fig. 368) and transmits the nasolacrimal duct. More anteriorly the bone is marked by an oblique ridge, termed the *conchal crest*, for articulation with the inferior nasal concha.

The shallow concavity below this ridge forms part of the inferior meatus of the nose, and the surface above the ridge part of the atrium of the middle meatus.

The **maxillary sinus** (figs. 382, 383) is a large pyramidal cavity within the body of the maxilla. Its walls are thin and correspond to the nasal, orbital, anterior, and posterior surfaces of the body of the bone. Its *apex*, which is directed laterally, is formed by the zygomatic process; its *base*, or nasal wall, which faces medially, is formed by the lateral wall of the nose and presents the maxillary hiatus in the disarticulated bone. In the articulated skull this aperture is much reduced in size by the following bones: the uncinate process of the ethmoid and the descending part of the lacrimal bone above, the maxillary process of the inferior nasal concha below, and the perpendicular plate of the palatine bone behind (figs. 368, 383). The maxillary sinus communicates with the middle meatus of the nose, generally by two small apertures, one of which is usually closed by mucous membrane in the recent state. The *posterior wall* is pierced by the *dental canals*, which transmit the posterior superior dental vessels and nerves to the molar teeth; these canals occasionally project ridges into the maxillary sinus. The floor is formed by the alveolar

FIG. 382.—The left maxilla. Medial aspect.



process of the maxilla, and its lowest part is usually about 1·25 cm. below the level of the floor of the nasal cavity. In a large proportion of bones radiating septa of varying sizes spring from the floor of the sinus in the intervals between adjacent teeth; in some cases the floor is perforated by the fangs of the molar teeth.* The infra-orbital canal usually projects into the sinus a well-marked ridge extending from the *roof* to the *anterior wall*. The size of the cavity varies in different skulls, and even on the two sides of the same skull.† (Pl. I.)

Applied Anatomy.—The extreme thinness of the walls of this cavity affords an explanation of the fact that a tumour growing from the maxillary sinus and encroaching upon the adjacent parts may push up the floor of the orbit, and displace the eyeball; may project into the nose; may protrude forwards on to the cheek; or may make its way backwards into the infratemporal fossa, or downwards into the mouth.

The **zygomatic process** of the maxilla is a rough, pyramidal eminence, situated at the angle of separation of the anterior, posterior and orbital surfaces. *In front* it forms part

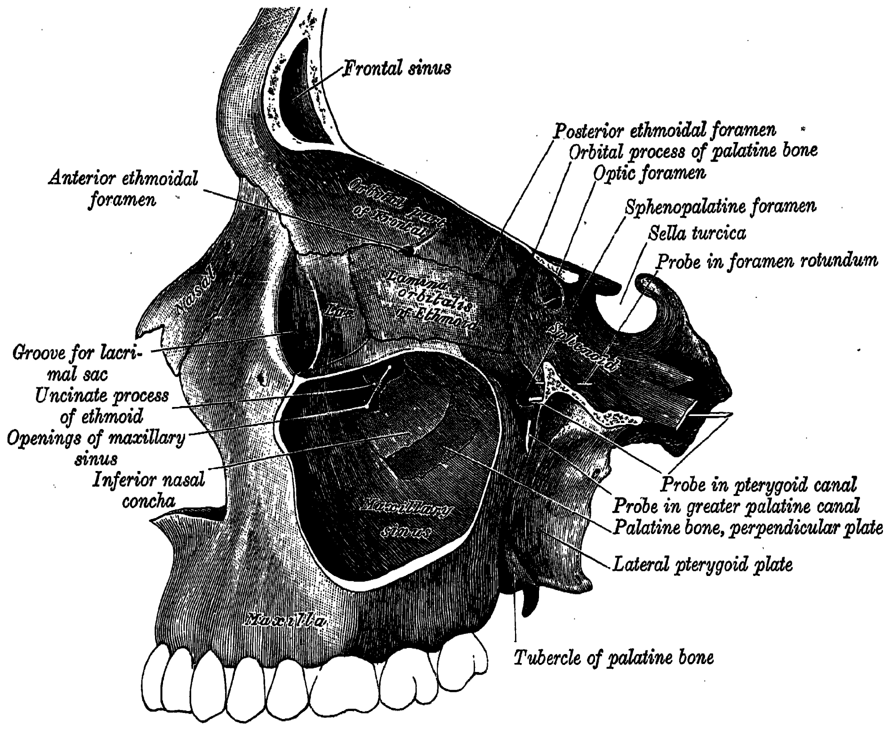
* The number of teeth whose roots are in relation with the floor of the maxillary sinus is variable. The sinus may extend so as to be in relation to all the teeth of the true maxilla, from the canine to the third molar.—(Salter.)

† Logan Turner (*op. cit.*) gives the following measurements for an adult sinus of average size: vertical height opposite first molar tooth, 3·5 cm.; transverse breadth, 2·5 cm.; and anteroposterior depth, 3·2 cm.

of the anterior surface of the body of the bone; *behind*, it is concave, and continuous with the posterior surface; *above*, it is rough and serrated for articulation with the zygomatic bone; *below*, it presents a prominent arched border, which separates the anterior from the posterior surface.

The **frontal process** of the maxilla projects upwards and backwards between the nasal and lacrimal bones (figs. 330, 383). Its *lateral surface* (fig. 380) is divided by a vertical ridge, termed the *lacrimal crest*, which gives attachment to the medial palpebral ligament and is continuous below with the infra-orbital margin. At the junction of the crest with the orbital surface there is a small tubercle, which serves as a guide to the position of the lacrimal sac. The part in front of the lacrimal crest is smooth and merges below with the anterior surface of the body; it gives attachment to a portion of the orbicularis oculi and to the levator labii superioris alæque nasi (angular head of the quadratus labii superioris). Behind the lacrimal crest there is a vertical groove which assists the groove on the lacrimal bone to complete the *lacrimal groove* for the lodgement of the lacrimal sac.

FIG. 383.—The left maxillary sinus. Opened from the lateral side.



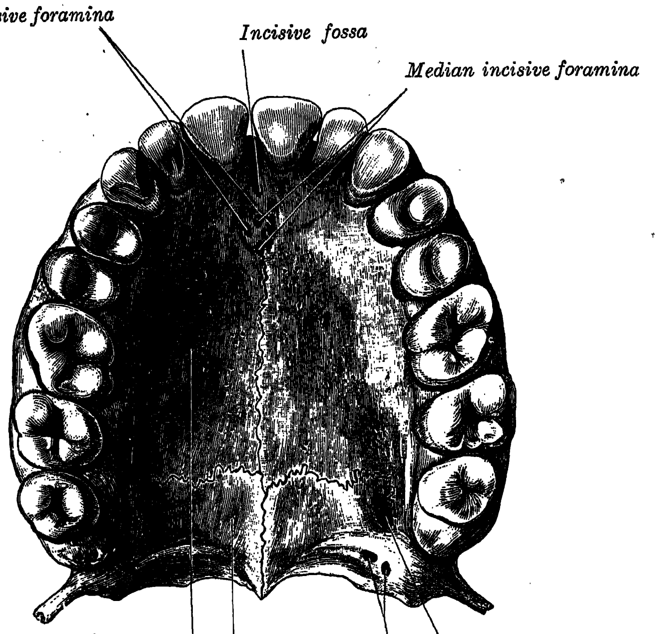
The *medial surface* of the frontal process (fig. 382) forms a portion of the lateral wall of the nasal cavity. A rough, uneven area at its upper part articulates with the ethmoid bone and closes the anterior ethmoidal sinuses. Below this rough area there is an oblique ridge, termed the *ethmoidal crest*, the posterior part of which articulates with the middle nasal concha, while the anterior part is termed the *agger nasi*; the ethmoidal crest forms the upper limit of the atrium of the middle meatus of the nose. The *upper end* of the frontal process articulates with the nasal notch of the frontal bone, the *anterior border* with the nasal bone, and the *posterior border* with the lacrimal bone.

The **alveolar process** of the maxilla is thick and arched, broader behind than in front, and excavated to form sockets (alveoli) for the reception of the roots of the teeth. These cavities are eight in number and vary in size and depth according to the teeth they contain. That for the canine tooth is the deepest; those for the molars are the widest, and are subdivided into three minor sockets by septa; those for the incisors and the second premolar are single; that for the first premolar is sometimes divided into two. The buccinator muscle arises from the outer surface of this process, as far forward as the first molar tooth. When the maxillæ are articulated with each other, their alveolar processes together form the *alveolar arch*.

The **palatine process** of the maxilla, which is thick and strong, is horizontal and projects medially from the lowest part of the nasal surface of the bone. It forms a considerable part of the floor of the nasal cavity and the roof of the mouth, and is much thicker in front than

behind. Its *inferior surface* (fig. 384) is concave, rough and uneven, and forms, with the palatine process of the opposite bone, the anterior three-fourths of the bony palate. It is marked by numerous foramina for the passage of the nutrient vessels and presents depressions for the lodgement of the palatine glands; it is channelled at the posterior part of its lateral border by two grooves, which lodge the greater palatine vessels and nerve (descending palatine vessels and the anterior palatine nerve). When the two maxillæ are articulated, a funnel-shape depression, termed the *incisive fossa* (incisive foramen), is seen in the median plane, immediately behind the incisor teeth. In this opening the orifices of two lateral canals are visible: they are named the *incisive canals*; each leads upwards into the corresponding half of the nasal cavity and transmits the terminal branch of the greater palatine artery and the long sphenopalatine nerve. Occasionally there are two additional apertures in the median plane; they are termed the *anterior* and *posterior incisive foramina*, and, when present, transmit the long sphenopalatine nerves, the left passing through the anterior, and the right through the posterior foramen. On the under surface of the palatine process, a delicate

FIG. 384.—The bony palate and the alveolar arch. Inferior aspect.



suture, well seen in young skulls, may sometimes be noticed extending laterally and forwards from the incisive fossa to the interval between the lateral incisor and the canine teeth. The small part in front of this suture constitutes the *os incisivum* (premaxilla), which in most vertebrates forms an independent bone: it includes the whole thickness of the alveolus, the corresponding part of the floor of the nose and the anterior nasal spine, and contains the sockets of the incisor teeth. The *upper surface* of the palatine process is concave from side to side, smooth, and forms the greater part of the floor of the nasal cavity; close to the anterior part of its medial margin the bone is pierced by the upper orifice of the incisive canal. The *lateral border* of the process is fused with the rest of the bone. The *medial border*, thicker in front than behind, is raised into a ridge, termed the *nasal crest*, which, with the corresponding ridge of the opposite bone, forms a groove for the reception of the vomer. The front part of this ridge rises to a considerable height and is sometimes named the *incisor crest* (fig. 382); it is prolonged forwards into a sharp process, which, with the similar process of the opposite bone, forms the *anterior nasal spine*. The *posterior border* is serrated for articulation with the horizontal plate of the palatine bone.

Ossification.—The maxilla is developed mainly in membrane. Mall * and Fawcett † have

* *American Journal of Anatomy*, vol. v. 1906.

† *Journal of Anatomy and Physiology*, vol. xlv. 1911.

shown that it is ossified from two principal centres, one for the maxilla proper and one for the os incisivum (premaxilla). These centres appear about the end of the sixth week of intrauterine life, that for the maxilla proper above the canine tooth-germ, and that for the os incisivum above the incisor tooth-germs; the latter centre grows upwards and forms the anterior part of the frontal process. These two centres unite at the end of the second or early in the third month, but the suture between them (fig. 386) may persist on the palate until nearly middle life. At a later stage an additional centre (*prevomerine* or *paraseptal centre*) appears for the os incisivum on the medial side of the corresponding paraseptal cartilage. The maxillary sinus appears as a shallow groove (fig. 387) on the nasal surface

Fig. 385.—The right maxilla at birth. Lateral aspect.

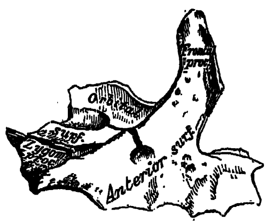
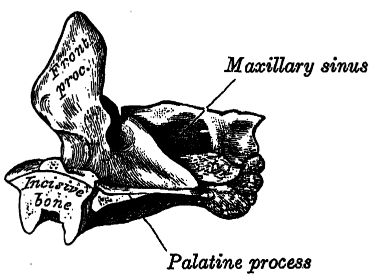


Fig. 386.—The right maxilla at birth. Inferior aspect.

Fig. 387.—The right maxilla at birth. Medial aspect.



of the bone about the fourth month of intrauterine life, but does not reach its full size until after the second dentition. The infra-orbital vessels and nerve lie for a time in an open groove in the floor of the orbit; the anterior part of this groove is converted into the infra-orbital canal by a lamina of bone which grows from the lateral side of the groove.

Changes produced in the Maxilla by Age

At birth the transverse and anteroposterior diameters of the maxilla are each greater than the vertical. The frontal process is well-marked, but the body of the bone consists of little more than the alveolar process, the tooth-sockets reaching almost to the floor of the orbit. The maxillary sinus is seen as a furrow on the lateral wall of the nose. In the adult the vertical diameter is the greatest, owing to the development of the alveolar process and the increase in size of the sinus. In old age the bone reverts in some measure to the infantile condition: its height is diminished and, after the loss of the teeth, the alveolar process is absorbed (p. 282), and the lower part of the bone contracted and reduced in thickness.*

The Palatine Bones (Ossa Palatina)

The **palatine bones** are situated at the posterior part of the nasal cavity, between the maxillæ and the pterygoid processes of the sphenoid bone (fig. 368). Each assists in forming the floor and lateral wall of the nasal cavity, the roof of the mouth, and the floor of the orbit, and enters into the formation of the pterygopalatine and pterygoid fossæ and the inferior orbital fissure.

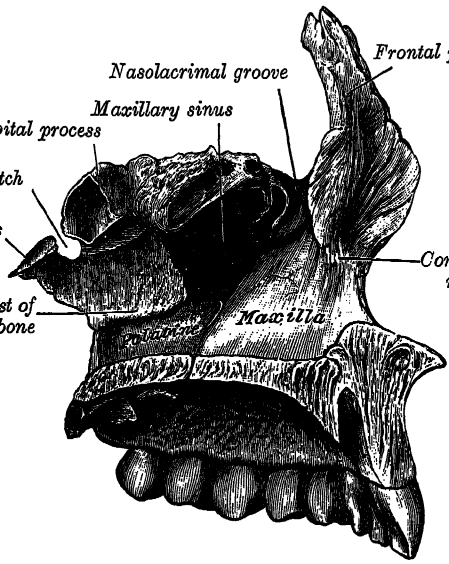
The palatine bone bears some resemblance to the letter L, and consists of a horizontal and a perpendicular plate, and three processes—viz. the tubercle (pyramidal process), which

* See references in footnote on p. 282.

is directed backwards, laterally and downwards from the junction of the horizontal and perpendicular plate, and the orbital and sphenoidal processes, which surmount the perpendicular plate and are separated by a deep notch, named the sphenopalatine notch.

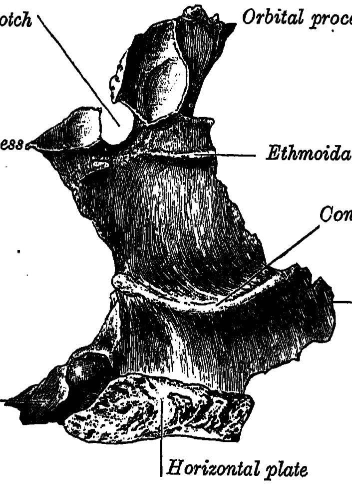
The **horizontal plate** of the palatine bone (figs. 384, 389) is quadrilateral and has two surfaces and four borders. The *nasal surface*, concave from side to side, forms the posterior

FIG. 388.—The articulation of the left palatine bone with the left maxilla.



part of the floor of the nasal cavity. The *palatine surface* forms, with the corresponding surface of the opposite bone, the posterior one-fourth of the bony palate; near its posterior margin there is a curved ridge, termed the *palatine crest*. The *posterior border* is thin and concave; to it, and to the palatine surface as far forwards as the palatine crest, the expanded

FIG. 389.—The left palatine bone. Medial aspect. (Enlarged.)



tendon of the tensor palati is attached. The medial end of the posterior border is pointed and, when united with that of the opposite bone, forms a projecting process, which gives attachment to the musculus uvulæ, and is named the *posterior nasal spine*. The *anterior border* is serrated and articulates with the palatine process of the maxilla. The *lateral border* is united with the inferior border of the perpendicular plate and is grooved by the lower end

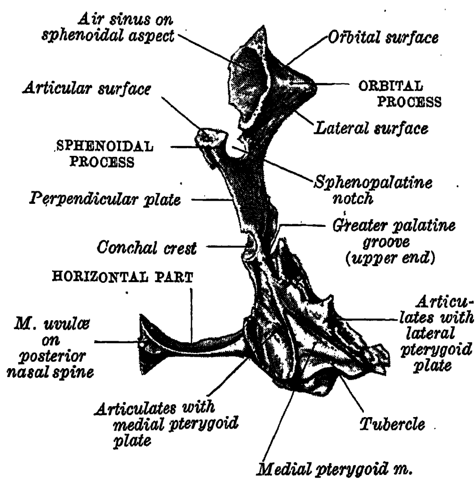
of the greater palatine groove (pterygopalatine sulcus). The *medial border*, which is thick and serrated, articulates with the corresponding border of the opposite bone, and the opposed borders form the *nasal crest*. This crest articulates with the posterior part of the lower edge of the vomer and is continuous anteriorly with the nasal crest of the maxillæ.

The **perpendicular plate** of the palatine bone (figs. 389, 390) is thin and of an oblong form, and has two surfaces and four borders.

The *nasal surface* exhibits at its lower part a broad, shallow depression which forms part of the inferior meatus of the nasal cavity. Immediately above this the *conchal crest* forms a horizontal ridge for articulation with the inferior nasal concha; still higher there is a second broad, shallow depression, which forms part of the middle meatus and is limited above by the *ethmoidal crest* for articulation with the middle nasal concha. Above the ethmoidal crest there is a narrow, horizontal groove, which forms part of the superior meatus.

The *maxillary surface* is rough and irregular throughout the greater part of its extent, for articulation with the nasal surface of the maxilla; its upper and posterior part is smooth and forms the medial wall of the pterygopalatine fossa; its front portion, which is also smooth, projects beyond the posterior border of the maxillary hiatus and forms the posterior part of the medial wall of the maxillary sinus (fig. 383). On the posterior part of the maxillary surface there is a deep vertical groove, named the *greater palatine groove* (*pterygopalatine sulcus*), which in the articulated skull is converted into the *greater palatine canal* (*pterygopalatine canal*) by the maxilla; this canal transmits the greater palatine (descending palatine) vessels and nerves.

Fig. 390.—The right palatine bone. Posterior aspect.



The *anterior border* is thin and irregular; at the level of the conchal crest a pointed, projecting lamina is directed forwards below and behind the maxillary process of the inferior nasal concha. It articulates with the latter and assists in forming the medial wall of the maxillary sinus (fig. 383). The *posterior border* (fig. 390) is serrated for articulation with the medial pterygoid plate of the sphenoid bone. This border is continuous above with the sphenoidal process; it expands below into the tubercle (pyramidal process) of the palatine bone. The *superior border* supports the orbital process in front and the sphenoidal process behind. These processes are separated by the *sphenopalatine notch*, which is converted into the *sphenopalatine foramen* by the under surface of the body of the sphenoid. In the articulated skull this foramen leads from the pterygopalatine fossa into the posterior part of the superior meatus of the nose, and transmits the sphenopalatine vessels and nerves. The *inferior border* is fused with the lateral border of the horizontal plate and, in front of the tubercle (pyramidal process), is marked by the lower end of the greater palatine groove.

The **tubercle (pyramidal process)** of the palatine bone projects backwards, laterally, and downwards from the junction of the horizontal and perpendicular plates of the bone, and fits into the angular interval between the lower ends of the pterygoid plates. On its *posterior surface* there is a smooth, grooved, triangular area, limited on each side by a rough articular furrow. The furrows articulate with the pterygoid plates, while the grooved triangular area completes the lower part of the pterygoid fossa and gives origin to some fibres of the medial pterygoid muscle. The anterior part of the *lateral surface* is rough for articulation with the maxillary tuberosity; the posterior part consists of a smooth triangular area, which appears, in the articulated skull, at the lower part of the infratemporal fossa between the maxillary tuberosity and the lateral pterygoid plate (fig. 317). The *inferior surface* of the tubercle, close to its union with the horizontal plate of the bone, presents the *lesser palatine foramina* for the transmission of the lesser (middle and posterior) palatine nerves (fig. 384).

The **orbital process** of the palatine bone (figs. 389, 390) is directed upwards and laterally from the front of the perpendicular plate, to which it is joined by a constricted neck. It encloses an air-sinus, and presents three articular and two non-articular surfaces. Of the articular surfaces: (1) the *anterior* or *maxillary*, of an oblong form, is directed forwards, laterally, and downwards, and articulates with the maxilla; (2) the *posterior* or *sphenoidal*,

directed backwards, upwards, and medially, presents the opening of the air-sinus, which usually communicates with the sphenoidal sinus; the margins of the opening articulate with the sphenoidal concha; (3) the *medial* or *ethmoidal* is directed medially and forwards, and articulates with the labyrinth of the ethmoid bone. In some cases, the air-sinus opens on this surface and then communicates with the posterior ethmoidal sinuses; more rarely it opens on the ethmoidal and sphenoidal surfaces, and then communicates with the posterior ethmoidal sinuses and the sphenoidal sinus. Of the non-articular surfaces: (1) the *superior* or *orbital*, triangular in shape, is directed upwards and laterally, and forms the posterior part of the floor of the orbit; and (2) the *lateral*, of an oblong form, is directed towards the pterygopalatine fossa and is separated from the orbital surface by a rounded border, which forms the medial part of the lower margin of the inferior orbital fissure; the lower part of this surface may present a groove, directed laterally and upwards, which lodges the maxillary nerve and is continuous with the groove on the upper part of the posterior surface of the maxilla (p. 317). The border between the lateral and posterior surfaces is prolonged downwards as the anterior boundary of the sphenopalatine notch.

The **sphenoidal process** of the palatine bone (figs. 389, 390) is a thin, compressed plate, smaller and on a lower level than the orbital process; it is directed upwards and medially. Its *superior surface* articulates with the under surface of the sphenoidal concha and the root of the medial pterygoid plate; it presents a groove which contributes to the formation of the palatinovaginal (pharyngeal) canal. The *inferomedial surface* is concave and forms a small part of the roof and lateral wall of the nasal cavity. The posterior part of the *lateral surface* articulates with the medial pterygoid plate; the anterior part is smooth and forms a portion of the medial wall of the pterygopalatine fossa. The *posterior border* is rough and articulates with the vaginal process of the medial pterygoid plate. The *anterior border* forms the posterior boundary of the sphenopalatine notch. The *medial border* articulates with the ala of the vomer.

The orbital and sphenoidal processes are separated from each other by the *sphenopalatine notch*, which is converted into the sphenopalatine foramen by the under surface of the body of the sphenoid; sometimes the two processes are united by a spicule of bone which converts the notch into a foramen.

Ossification.—The palatine bone is ossified in membrane from one centre, which appears during the eighth week of intrauterine life in the perpendicular plate of the bone. From this point ossification spreads upwards into the orbital and sphenoidal processes, medially into the horizontal plate, and downwards into the tubercle.

At the time of birth the height of the perpendicular plate is about equal to the transverse width of the horizontal plate, whereas in the adult it measures nearly twice as much.

The Zygomatic Bones [Ossa Zygomatica]

The **zygomatic bones** are situated in the upper and lateral parts of the face. Each forms the prominence of the cheek, and contributes to the formation of the lateral wall and floor of the orbit and to the walls of the temporal and infratemporal fossæ (fig. 391).

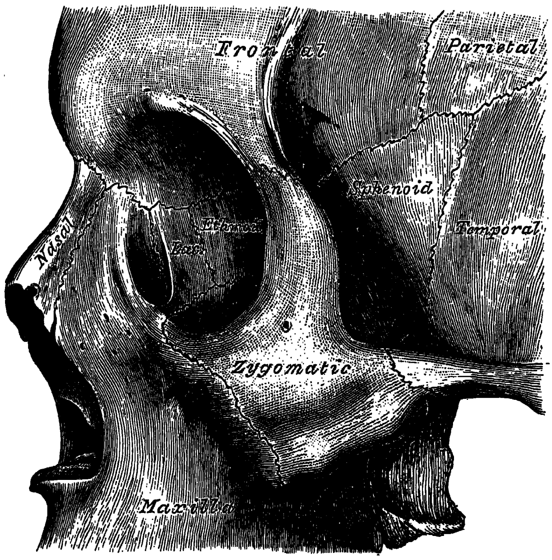
The zygomatic bone is quadrangular in shape, but has a flange-like projection from the anterior part of its medial aspect. It has three surfaces, five borders and two processes.

The *lateral surface* (figs. 391, 392), directed laterally and forwards, is convex and is pierced near its orbital border by the *zygomaticofacial foramen* (which is often double), for the passage of the zygomaticofacial nerve and vessels; below this foramen a slight elevation gives origin to the zygomaticus minor (zygomatic head of quadratus labii superioris), and more posteriorly the zygomaticus major (zygomaticus) takes origin. The *temporal surface* (fig. 393), which is directed medially and backwards, is concave. It presents anteriorly a roughened area for articulation with the maxilla, and posteriorly a smooth, concave area, which extends upwards on the posterior aspect of the frontal process to form the anterior boundary of the temporal fossa. It also extends backwards on the medial aspect of the temporal process to form an incomplete lateral wall for the infratemporal fossa. The *zygomaticotemporal foramen*, for the transmission of the nerve of the same name, pierces this surface near the base of the frontal process. The *orbital surface* (fig. 393), smooth and concave, forms the anterolateral part of the floor and the adjoining part of the lateral wall of the orbit, extending upwards on to the medial aspect of the frontal process. It usually presents the orifices of two canals, termed the *zygomatico-orbital foramina*, one of which leads to the zygomaticofacial and the other to the zygomaticotemporal foramen.

The *anterosuperior* or *orbital border* is smooth and concave, and forms a considerable part of the circumference of the orbital opening, below and on the lateral side. It separates the orbital from the lateral surface. The *antero-inferior* or *maxillary border* is rough and articulates with the maxilla; its medial extremity is pointed and lies above the infraorbital foramen: near the orbital margin it gives origin to a part of the levator labii

superioris. The *posterosuperior* or *temporal border* is curved like the italic letter *f*, and is continuous above with the posterior border of the frontal process and below with the upper border of the zygomatic arch; it gives attachment to the temporal fascia. A little below the frontozygomatic suture this border presents a small, rounded projection, termed the

FIG. 391.—The left zygomatic bone *in situ*.



marginal tubercle, which can be felt easily through the skin. The *postero-inferior* or *zygomatic border* affords attachment by its rough edge to the masseter muscle. The *posteromedial border* is serrated for articulation with the greater wing of the sphenoid above, and the orbital surface of the maxilla below. Between these two serrated portions there is usually a short, concave, nonarticular part, which forms the lateral boundary of the inferior orbital

FIG. 392.—The left zygomatic bone. Lateral aspect.

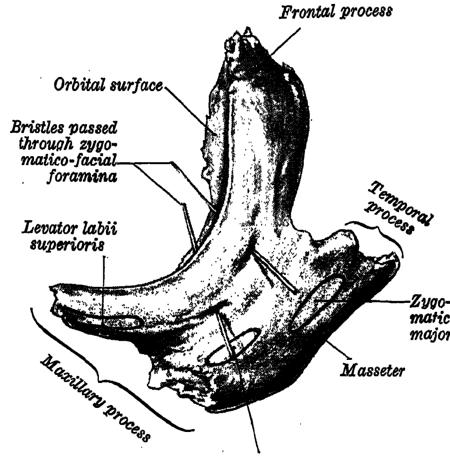
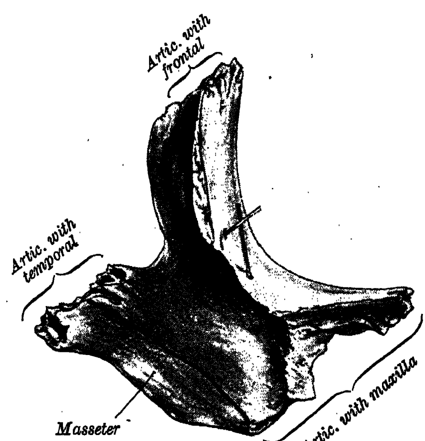


FIG. 393.—The left zygomatic bone. Medial aspect.



fissure. This non-articular part is sometimes absent, and the fissure is then completed by the junction of the maxilla and the sphenoid bone, or by the interposition of a small sutural bone in the angular interval between them.

The *frontal process* is thick and serrated; it articulates above with the zygomatic process of the frontal bone and behind with the greater wing of the sphenoid. On its orbital aspect, just within the orbital opening and about 11 mm. below the frontozygomatic suture, there

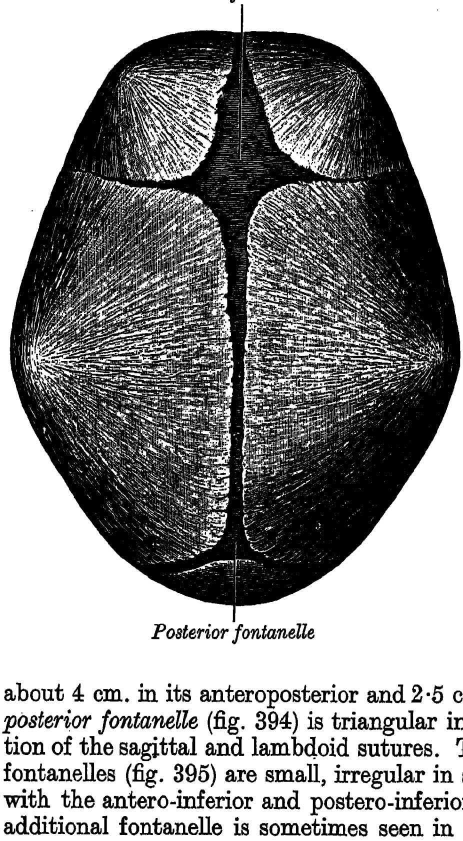
is a tubercle of varying size and form, but present in 95 per cent. of skulls (Whitnall).* The *temporal process* is directed backwards and ends in an oblique, serrated margin which articulates with the zygomatic process of the temporal bone, and helps to form the zygomatic arch.

Ossification.—The zygomatic bone is ossified from one centre, which appears about the eighth week of intrauterine life. The bone is sometimes divided by a horizontal suture into an upper larger, and a lower smaller division.

The Differences in the Skull due to Age

At birth the skull is large in proportion to the other parts of the skeleton, but the base is short and narrow in proportion to the vault; the facial portion is small and equals only about one-eighth of the size of the cranium as compared with one-half in the adult. The frontal and parietal eminences are prominent, and when the skull is viewed from above it presents a pentagonal outline with its greatest width at the parietal eminences (fig. 394); on the other hand, the glabella, superciliary arches, and mastoid processes are not developed. Ossification of the skull bones is not completed, and many of them—e.g. the occipital, temporals, sphenoid, frontal, and mandible—consist of more than one piece. Unossified membranous intervals, termed fontanelles (fonticuli), are seen at the angles of the parietal bones; these fontanelles are six in number; two, the anterior and posterior, are situated in the median plane, and two, the anterolateral and posterolateral, on each side.

Fig. 394.—The skull at birth, showing the anterior and posterior fontanelles. Superior aspect.



The *anterior fontanelle* (fig. 394) is the largest, and is placed at the junction of the sagittal, coronal, and frontal sutures; it is lozenge-shaped, and measures about 4 cm. in its anteroposterior and 2·5 cm. in its transverse diameter. The *posterior fontanelle* (fig. 394) is triangular in form and is situated at the junction of the sagittal and lambdoid sutures. The anterolateral and posterolateral fontanelles (fig. 395) are small, irregular in shape, and correspond respectively with the antero-inferior and postero-inferior angles of the parietal bones. An additional fontanelle is sometimes seen in the sagittal suture at the region of the obelion (p. 328).

The fontanelles are usually closed by the growth and extension of the bones which surround them, but sometimes they are the sites of separate centres of ossification which develop into sutural bones. The posterior and anterolateral fontanelles are obliterated within two or three months after birth; the posterolateral fontanelle is usually closed about the end of the first year, and the anterior fontanelle about the middle of the second year.

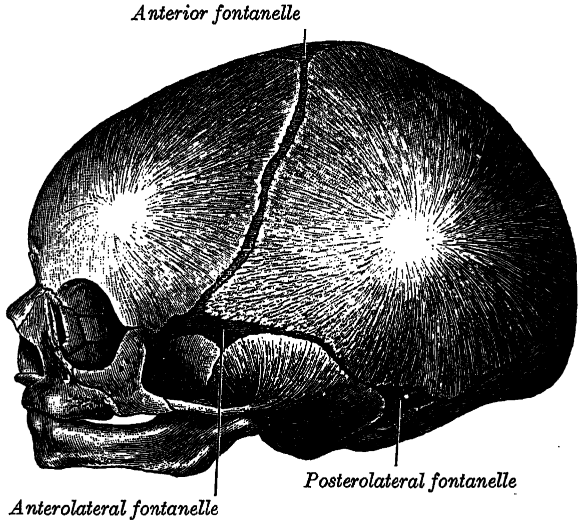
The smallness of the face at birth is mainly accounted for by the rudimentary condition of the mandible and maxillæ, the non-eruption of the teeth, and the

* S. E. Whitnall, *The Anatomy of the Human Orbit*, 1921.—The structures attached to this tubercle are: (1) the 'check ligament' of the rectus lateralis; (2) part of the aponeurosis of the levator palpebræ superioris; (3) the suspensory ligament of the eyeball; and (4) the lateral palpebral ligament.

small size of the maxillary sinuses and nasal cavity. At birth the nasal cavity lies almost entirely between the orbits, and the lower border of the anterior nasal aperture is only a little below the level of the orbital floor. With the eruption of the deciduous teeth there is an enlargement of the face and jaws, and these changes are still more marked after the second dentition.

The skull grows rapidly from birth to the seventh year, but the greater part of the increase of its cranial part occurs during the first year owing to the rapidity of the growth of the brain in that period (p. 123). Growth in length occurs at the coronal suture and at the other sutures which are parallel with it; growth in breadth, at the sagittal and parallel sutures; growth in height, at the parietotemporal and at the other sutures which lie in a transverse plane. Towards the end of the second year the mastoid process makes its appearance, and the tympanic ring lengthens to form the bony part of the external auditory meatus (p. 302). As a result the styloid process and the stylomastoid foramen, which are relatively superficial in the newly-born child, become more deeply

FIG. 395.—The skull at birth, showing the anterolateral and posterolateral fontanelles. Left lateral aspect.



situated. At the seventh year the cribriform plate of the ethmoid bone, the foramen magnum, and the petrous parts of the temporal bones have reached their full size, and the orbits are only a little smaller than those of the adult. Growth is slow from the seventh year until the approach of puberty, when a second period of increased activity occurs: this results in an enlargement in all directions, but especially in the frontal and facial regions, where it is associated with the development of the air-sinuses. The enlargement of the cranium is effected, in its latter stages, by absorption from the inner surface and by bone deposition on the outer surface. This process chiefly affects the bones of the vault and of the lateral aspects of the skull.

Obliteration of the sutures of the vault of the skull takes place as age advances. It may commence between the ages of thirty and forty on the inner surface, and about ten years later on the outer surface of the skull, but the times at which the sutures are closed are subject to great variations. Obliteration usually occurs first in the lower part of the coronal suture, next in the posterior part of the sagittal suture, and then in the lambdoid suture.

In old age the skull generally becomes thinner and lighter, but in a small proportion of cases it increases in thickness and weight. The most striking feature of the senile skull is the diminution in the size of the mandible and maxillæ consequent on the loss of the teeth and the absorption of the alveolar processes. This is associated with a marked reduction in the vertical measurement of the face and with an alteration in the angles of the mandible (p. 282).

The Sex Differences in the Skull

Until the age of puberty there is little difference between the skull of the female and that of the male. The skull of an adult female is as a rule lighter and smaller, and its capacity is about 10 per cent. less, than that of the male. Its walls are thinner and its muscular ridges less marked; the glabella, superciliary arches, and mastoid processes are less prominent, and the corresponding air-sinuses are small or rudimentary. The upper margin of the orbit is sharp, the forehead vertical, the frontal and parietal eminences prominent, and the vault somewhat flattened. The contour of the face is rounder, the facial bones are smoother, and the mandible and maxillæ and their contained teeth smaller. Speaking generally, more of the infantile characteristics are retained in the skull of the adult female than in that of the adult male. A well-marked male or female skull can easily be recognised as such, but in some skulls the respective characteristics are so indistinct that the determination of the sex may be difficult or impossible.*

Craniology

Skulls vary in size and shape, and the term craniology is applied to the study of these variations.

The *capacity* of the cranial cavity constitutes a good index of the size of the brain which it contained, and is most conveniently arrived at by filling the cavity with shot and measuring the contents in a graduated vessel. Skulls may be classified according to their capacities as follows:

1. *Microcephalic*, with a capacity of less than 1350 c.cm.—e.g. those of native Australians and Andaman Islanders.
2. *Mesocephalic*, with a capacity of from 1350 c.cm. to 1450 c.cm.—e.g. those of African negroes and Chinese.
3. *Megacephalic*, with a capacity of over 1450 c.cm.—e.g. those of Europeans, Japanese and Eskimos.

In comparing the shape of one skull with that of another it is necessary to adopt some definite position in which the skulls should be placed during the process of examination. They should be so placed that a line carried through the lower margin of the orbit and upper margin of the opening of the external auditory meatus is in the horizontal plane. The normæ of one skull can then be compared with those of another, and the differences in contour and surface-form noted. Further, it is necessary that the various linear measurements used to determine the shape of the skull should be made between definite and easily localised points on its surface. The principal points may be divided into two groups: (1) those in the median plane, and (2) those on either side of it (fig. 396).

The **points in the median plane** are the:

Pogonion. The most prominent point of the chin.

Alveolar point or *prosthion.* The central point of the anterior margin of the upper alveolar arch.

Akanthion. The tip of the anterior nasal spine.

Subnasal point. The middle of the lower border of the anterior nasal aperture, at the base of the anterior nasal spine.

Rhinion. The most prominent point of the internasal suture.

Nasion. The central point of the frontonasal suture.

Glabella. The point in the median plane at the level of the superciliary arches.

Ophryon. The point in the median plane of the forehead at the level where the temporal lines most nearly approach each other.

Bregma. The meeting point of the coronal and sagittal sutures.

Obelion. A point on the sagittal suture on a level with the parietal foramina.

Lambda. The point of junction of the sagittal and lambdoid sutures.

Occipital point. The point in the median plane of the occipital bone farthest from the glabella.

Inion. The most prominent point on the external occipital protuberance in the median plane.

Opisthion. The mid-point of the posterior margin of the foramen magnum.

Basion. The mid-point of the anterior margin of the foramen magnum.

* Some additional differences between the male and female skull are given by F. G. Parsons and Lucas Keene, *Journal of Anatomy*, vol. liv. 1919.

FIG. 1.—Radiograph of skull. Lateral view. Crosses are placed on the frontal, the maxillary and the sphenoidal sinuses. Behind the last-named, the hypophyseal fossa can be identified. The dense white area below and behind the fossa is due to the petrous part of the temporal bone.

FIG. 2.—Radiograph of adult skull. Frontal view. 1 =maxillary sinus ; 2 =frontal sinus. The arrow is directed towards the mastoid air-cells.

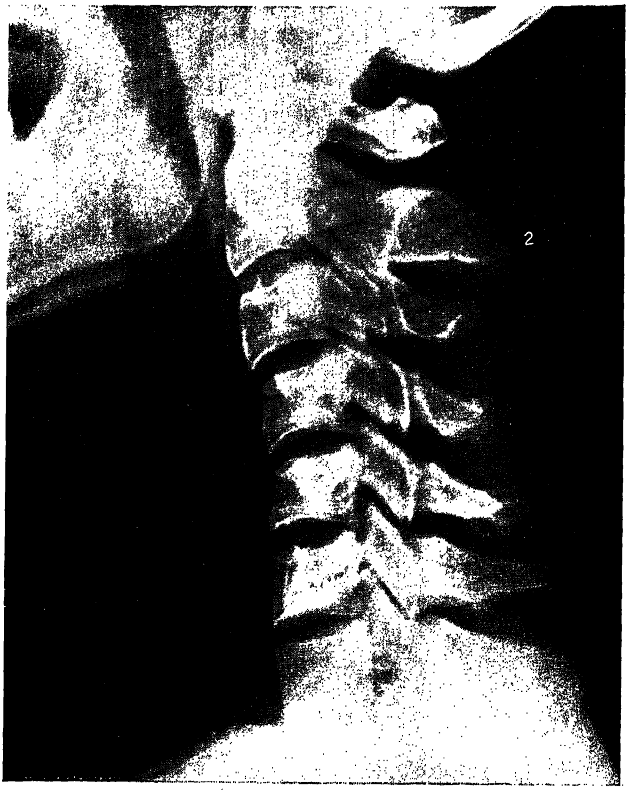


FIG. 1.—Radiograph of the cervical vertebræ. Lateral view. 1 = anterior arch of atlas; 2 = spine of axis. The curvature is abnormal.

FIG. 2.—Radiograph of the lumbar vertebræ, after intravenous injection of uroselectan, B. Anterior view. The ureters and their pelves, and the major and minor calyces are well shown. Note the cupping at the extremities of the minor calyces. Note also the relation of the ureter to the transverse processes and that the lateral edge of the left Psoas major muscle can be recognised. The arrow points to the shadow of the right kidney.

The points on each side of the median plane are the:

Gonion. The outer margin of the angle of the mandible.

Jugal point. The angle between the temporal border of the zygomatic bone and the upper border of the zygomatic arch.

Dacryon. The point of union of the anterosuperior angle of the lacrimal with the frontal bone and the frontal process of the maxilla.

Pterion. This point is the centre of the circular area of the same name (p. 251).

Stephanion. The point where the temporal line intersects the coronal suture.

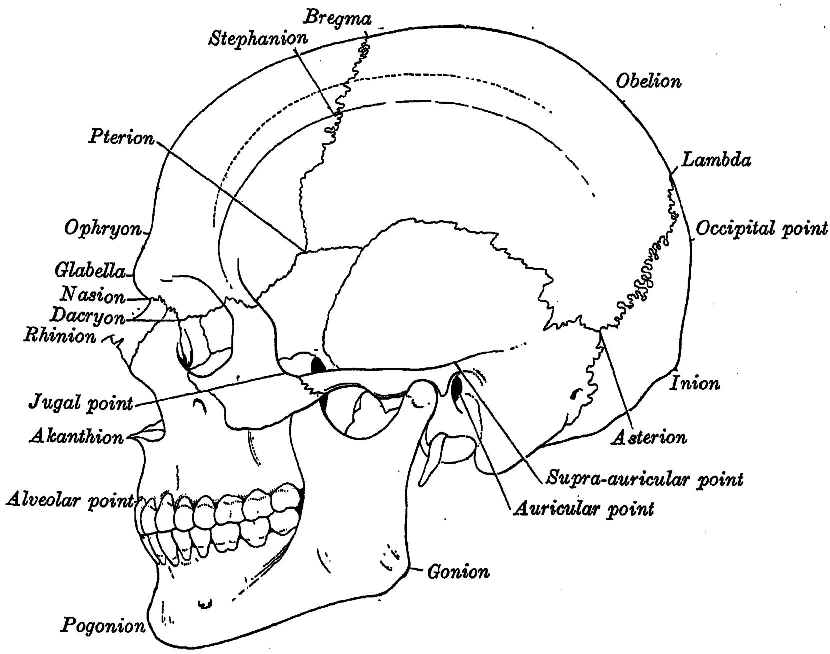
Auricular point. The centre of the orifice of the external auditory meatus.

Supra-auricular point. A point on the posterior root of the zygomatic arch, above the middle of the orifice of the external auditory meatus.

Asterion. The point of meeting of the lambdoid, occipitomastoid, and parietomastoid sutures.

The *horizontal circumference* of the cranium is measured in a plane passing through the glabella in front, and the occipital point behind; it averages about 50 cm. in the female and 52·5 cm. in the male.

FIG. 396.—An outline of the left side of the skull.



The *occipitofrontal* or *longitudinal arc* is measured from the nasion over the median plane of the vertex to the opisthion, while the basinasal length is the distance between the basion and the nasion. These two measurements, plus the anteroposterior diameter of the foramen magnum, represent the *vertical circumference* of the cranium.

The *length* is measured from the glabella to the occipital point, while the *breadth* or greatest transverse diameter is usually found a little above and behind the opening of the external auditory meatus. The proportion of breadth to length $\frac{\text{breadth} \times 100}{\text{length}}$ is termed the *cephalic index* or *index of breadth.*

The *height* is measured from the basion to the bregma, and the proportion of height to length $\frac{\text{height} \times 100}{\text{length}}$ constitutes the *vertical* or *height index.*

In studying the face the principal points to be noticed are the proportion of its length to its breadth, the shape of the orbits and of the anterior nasal aperture, and the degree of projection of the jaws.

The *length of the face* is measured from the nasion to the lower margin of the mandible, or, if the mandible be wanting, to the alveolar point; its *width* is the distance between the zygomatic arches. By comparing the length with the width of the face, skulls may be divided into two groups; *dolichofacial* (long-faced) and *brachyfacial* (short-faced).

The *orbital index* signifies the proportion which the orbital height bears to the orbital width, thus:

$$\frac{\text{orbital height} \times 100}{\text{orbital width}}$$

The *nasal index* expresses the proportion which the width of the anterior nasal aperture bears to the height of the nose, the latter being measured from the nasion to the subnasal point, thus:

$$\frac{\text{nasal width} \times 100}{\text{nasal height}}.$$

The degree of projection of the jaws is determined by the *gnathic* or *alveolar index*, which represents the proportion between the basi-alveolar and basinasal lengths, thus:

$$\frac{\text{basi-alveolar length} \times 100}{\text{basinasal length}}.$$

The *dental index* is arrived at by comparing the *dental length* (i.e. the distance between the anterior surface of the first premolar and the posterior surface of the third molar tooth of the maxilla) with the basinasal length, thus:

$$\frac{\text{dental length} \times 100}{\text{basinasal length}}.$$

The following table, modified from that given by Duckworth,* illustrates how some of these indices may be utilised in the classification of skulls:

INDEX.	CLASSIFICATION.	NOMENCLATURE.	EXAMPLES.
1. Cephalic .	Below 75 . . .	Dolichocephalic .	Kaffirs and Native Australians
	Between 75 and 80 .	Mesaticephalic .	Europeans and Chinese
	Above 80 . . .	Brachycephalic .	Mongolians and Andamans
2. Orbital .	Below 84 . . .	Microseme . .	Tasmanians and Native Australians
	Between 84 and 89 .	Mesoseme . .	Europeans
	Above 89 . . .	Megaseme . .	Chinese and Polynesians
3. Nasal .	Below 48 . . .	Leptorhine . .	Europeans
	Between 48 and 53 .	Mesorhine . .	Japanese and Chinese
	Above 53 . . .	Platyrhine . .	Negroes and Native Australians
4. Gnathic .	Below 98 . . .	Orthognathous .	Europeans
	Between 98 and 103 .	Mesognathous .	Chinese and Japanese
	Above 103 . . .	Prognathous .	Native Australians

Applied Anatomy.—The chief function of the skull is to protect the brain, and therefore those portions of the skull which are most exposed to external violence are thicker than those which are shielded from injury by overlying muscles. Thus, the skull-cap is thick and dense, whereas the squamous temporal, being protected by the temporal muscles, and the inferior occipital fossæ, being shielded by the muscles at the back of the neck, are thin and fragile. Additional features which tend to prevent fracture of the skull are its elasticity, its rounded shape, and its construction of a number of secondary elastic arches, each made up of a single bone. The manner in which vibrations are transmitted through the bones of the skull is also of importance as regards its protective mechanism, at all events as far as the base is concerned. In the vault, the bones being of a fairly equal thickness and density, vibrations are transmitted in a uniform manner in all directions, but in the base, owing to the varying thickness and density of the bones, this is not so; and therefore in this situation there are special buttresses which serve to carry the vibrations in certain definite directions. At the front of the skull, on each side, is the ridge which separates the anterior from the middle fossa of the base; and behind, the ridge or buttress which separates the middle from the posterior fossa; and if any violence is applied to the vault, the vibrations would be carried along these buttresses to the sella turcica, where they meet. This part has been termed the 'centre of resistance,' and here there is a special protective mechanism to guard the brain. The subarachnoid cavity at the base of the brain is dilated, and the cerebrospinal fluid which fills it acts as a water-cushion to shield the brain from injury. In like manner, when violence is applied to the base of the skull, as in falls upon the feet, the vibrations are carried backwards through the occipital crest, and forwards through the basilar part of the occipital and body of the sphenoid bone to the vault of the skull.

* W. L. H. Duckworth, *Morphology and Anthropology*, Cambridge University Press.

Fractures of the vault of the skull generally involve the whole thickness of the bone; but sometimes the inner table alone is fractured, and portions of it driven inwards. In fractures of the skull, and especially in punctured fractures, the inner table is more splintered and comminuted than the outer, and this is due to several causes. It is thinner and more brittle; the force of the violence as it passes inwards becomes broken up and is more diffused by the time it reaches the inner table; the bone being in the form of an arch bends as a whole and spreads out, and thus presses the particles together on the convex surface of the arch, i.e. the outer table, and forces them asunder on the concave surface or inner table; and, lastly, there is nothing firm under the inner table to support it and oppose the force.

The most common place for fracture of the base to occur is through the middle fossa, and here the fissure usually takes a fairly definite course. Starting from the point struck, which is generally somewhere in the neighbourhood of the parietal eminence, it runs downwards through the parietal and the squamous temporal and across the petrous portion, frequently traversing and implicating the internal auditory meatus, to the foramen lacerum. From this it may pass across the body of the sphenoid, through the sella turcica, to the foramen lacerum of the other side, and may indeed travel round the whole cranium so as to separate completely the anterior from the posterior part. The course of the fracture explains the symptoms to which fracture in this region may give rise: thus if the fissure passes across the internal auditory meatus injury to the facial and auditory nerves may result, with consequent facial paralysis and deafness; if the fissure extends through the semicircular ducts giddiness will be complained of, especially on turning the head sideways; or the tubular prolongation of the arachnoid around the nerves in the meatus may be torn and thus permit of the escape of the cerebrospinal fluid, should there be a communication between the internal ear and the tympanic cavity together with rupture of the tympanic membrane, as is frequently the case: again, if the fissure passes across the sella turcica, and the mucoperiosteum covering the under surface of the body of the sphenoid bone is torn, blood will find its way into the pharynx and be swallowed, and after a time vomiting of blood will result. Fractures of the anterior fossa, involving the bones forming the roof of the orbit and nasal cavity, are generally the result of blows on the forehead; but fracture of the cribriform plate of the ethmoid may be a complication of fracture of the nasal bone. When the fracture implicates the roof of the orbit, the blood finds its way into this cavity, and travelling forwards, appears as a subconjunctival ecchymosis. If the roof of the nasal cavity be fractured, the blood escapes from the nose. In rare cases there may be also escape of cerebrospinal fluid from the nose, should the dura mater and arachnoid have been torn.

The bones of the face are sometimes fractured as the result of direct violence. Those most commonly broken are the nasal bones and the mandible; the latter is by far the most frequently fractured of all the facial bones. Fracture of the *nasal bone* is for the most part transverse, and takes place about 1·25 cm. from the free margin. The broken portion may be displaced backwards or more generally to one side by the force which produced the lesion. The most common situation for a fracture of the *mandible* is in the neighbourhood of the canine tooth, as at this spot the bone is weakened by the deep socket for the root of this tooth; it is next most frequently fractured at the angle; then at the symphysis; and finally the neck of the mandible or the coronoid process may be broken. Occasionally a double fracture may occur, one in either half of the bone. The fractures are usually compound, from laceration of the mucous membrane covering the gums.

THE LIMBS

The upper and lower limbs are constructed after a common type, but the different functions for which they have become adapted in man have led to structural differences of a very definite kind. Each limb has a girdle, which connects it to the trunk, and three segments. The terminal segment in the upper limb is the hand and is specially adapted for prehension. In the lower limb the terminal segment is the foot and is primarly adapted to constitute an efficient supporting base for the body in the erect attitude, but it is, at the same time, constructed in such a manner as to facilitate locomotion (p. 516). In order that the full benefit of the prehensile character of the hand may be obtained, the living upper limb is characterised by the wide range of movement which it enjoys—in some situations, e.g. the shoulder-joint, actually at the expense of stability. In the living lower limb, on the other hand, the demand for stability is the prime factor, and stability is assured, even although some degree of mobility may be sacrificed for the purpose.

The bones by which the upper and lower limbs are attached to the trunk constitute, respectively, the shoulder and pelvic girdles. The *shoulder girdle*,

which is formed by the scapulæ and the clavicles, is deficient both in front and behind. In front, however, it is completed by the upper end of the sternum, with which the medial ends of the clavicles articulate. Behind, the scapulæ are separated from each other by a wide gap and are connected to the trunk by muscles only. The *pelvic girdle* is formed by the hip bones, which articulate with each other in front at the pubic symphysis so that the girdle is complete anteriorly. Posteriorly the girdle is incomplete, but the gap is filled by the upper part of the sacrum, with which the hip bones articulate. The pelvic girdle, with the sacrum, forms a complete ring, massive and comparatively rigid, in marked contrast with the lightness and mobility of the shoulder girdle.

THE BONES OF THE UPPER LIMB

THE SCAPULA (figs. 397, 398, 399)

General features.—The **scapula** is a large, flattened, triangular bone which lies on the posterolateral aspect of the chest wall, covering parts of the second to the seventh ribs. It presents for examination costal and dorsal surfaces, upper, lateral and medial borders, inferior, superior and lateral angles and three bony processes, viz., the spine, its continuation the acromion, and the coracoid process. The *lateral* angle is truncated and bears the glenoid cavity for articulation with the head of the humerus. This part of the bone may be regarded as the head, and it is connected to the plate-like body by an inconspicuous neck. The long axis of the scapula is nearly vertical and the relatively featureless *costal* surface can easily be distinguished from the *dorsal* surface, which is interrupted by the shelf-like projection of the spine (fig. 399). The bone is very much thickened in the immediate neighbourhood of the lateral border, which runs from the inferior angle *below*, to the glenoid cavity *above*. The student now possesses sufficient information to enable him to assign a given scapula correctly to its appropriate side of the body.

The *costal surface* (fig. 397), which is directed medially and forwards when the arm is by the side, is slightly hollowed out, especially in its upper part. Near the lateral border it presents a longitudinal, rounded ridge, stout and salient in the neighbourhood of the neck, but becoming less prominent below, which is separated from the lateral border by a narrow, grooved area. The *dorsal surface* (fig. 398) is divided into a smaller, upper area and a larger, lower area by a shelf-like projection, termed the *spine of the scapula.* These two areas communicate with each other through the *spinoglenoid notch,* which lies between the free, lateral border of the spine and the dorsal aspect of the neck of the bone. A flattened strip, for muscular attachments, marks the dorsal surface along the lateral border.

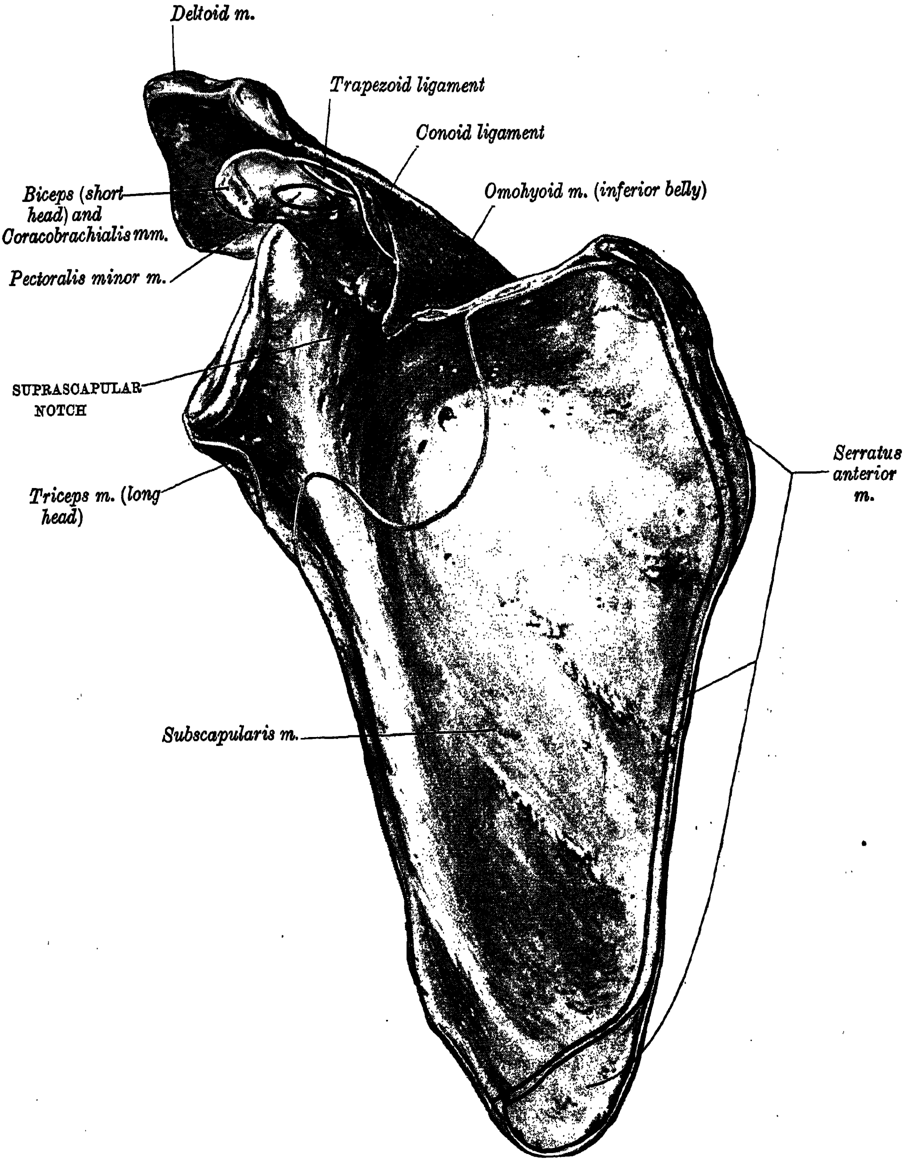
The *lateral border* (axillary border) of the scapula forms a sharp, roughened ridge,* which runs sinuously from the inferior angle to the glenoid cavity. At its upper end it widens into a rough, somewhat triangular, area, which is termed the *infraglenoid tubercle* (fig. 399). Throughout its whole length the lateral border is thickly covered with muscles and cannot be felt satisfactorily in the living subject. The *medial border* (vertebral border) of the scapula extends from the inferior to the superior angle. In its lower two-thirds this border can easily be felt through the skin, but its upper third is more deeply placed and cannot be palpated in the normal subject. The *superior border,* thin and sharp, is the shortest of the three borders. At its anterolateral end it is separated from the root of the coracoid process by the *suprascapular notch,* which is converted into a foramen by the suprascapular ligament.

The *inferior angle* lies over the seventh rib, or over the seventh intercostal space. It can be felt through the skin and the muscles which cover it and, when the arm is raised above the head, it can be seen to pass forwards round the chest wall. The *superior angle* is placed at the junction of the superior and medial

* The lateral border is often described as a thick border, but such a description includes in the border the grooved, lateral part of the costal surface and, frequently, the flattened strip along the lateral part of the dorsal surface. The actual border, however, is clearly defined on the bone as a narrow, roughened ridge (fig. 399).

borders, and is obscured by the muscles which cover it. The *lateral angle* is truncated and broadened. It constitutes the head of the bone. On its free surface it bears the *glenoid cavity* for articulation with the head of the humerus in the shoulder-joint. When the arm is by the side the glenoid cavity is directed forwards and laterally and slightly upwards. Very gently hollowed out, it forms a poor socket for the humeral head. It is narrow above and wider below, and is therefore

FIG. 397.—The right scapula. Costal aspect.



pear-shaped in outline. Immediately above the glenoid cavity a small roughened area encroaches on the root of the coracoid process and is termed the *supraglenoid tubercle*. The *neck* of the scapula is the constriction immediately adjoining the head. It can be identified most easily on its inferior and dorsal aspects. Ventrally, it can be regarded as extending between the infraglenoid tubercle and the anterior margin of the suprascapular notch.

The *spine of the scapula* (fig. 398) forms a shelf-like elevation on the upper part of the dorsal surface of the bone, and is triangular in shape. Its lateral border is

free, thick and rounded and helps to bound the *spinoglenoid notch*, which lies between it and the dorsal surface of the neck of the bone. Its anterior border joins the dorsal surface of the scapula along a line which runs laterally and slightly upwards from the junction of the upper and middle thirds of the medial border. It should be noted that the plate-like body of the bone is bent along this line, and this fact accounts for the concavity of the upper part of the costal surface. The third border is termed the *crest of the spine*, and is *subcutaneous throughout nearly its whole extent*. At its medial end the crest expands into a smooth, triangular area. Elsewhere the upper and lower edges and the surface of the crest are roughened for muscular attachments. The upper surface of the spine widens as it is traced laterally, and is slightly hollowed out. Together with the upper area of the dorsal surface of the bone, the upper surface of the spine forms the *supraspinous fossa*. The lower surface is overhung by the crest at its medial, narrow end, but is gently convex in its wider, lateral portion. Together with the lower area of the dorsal surface of the bone, the lower surface of the spine forms the *infraspinous fossa*, which communicates freely with the supraspinous fossa through the spinoglenoid notch. Both surfaces of the spine display large vascular foramina running towards the junction of the free, lateral border with the body of the bone.

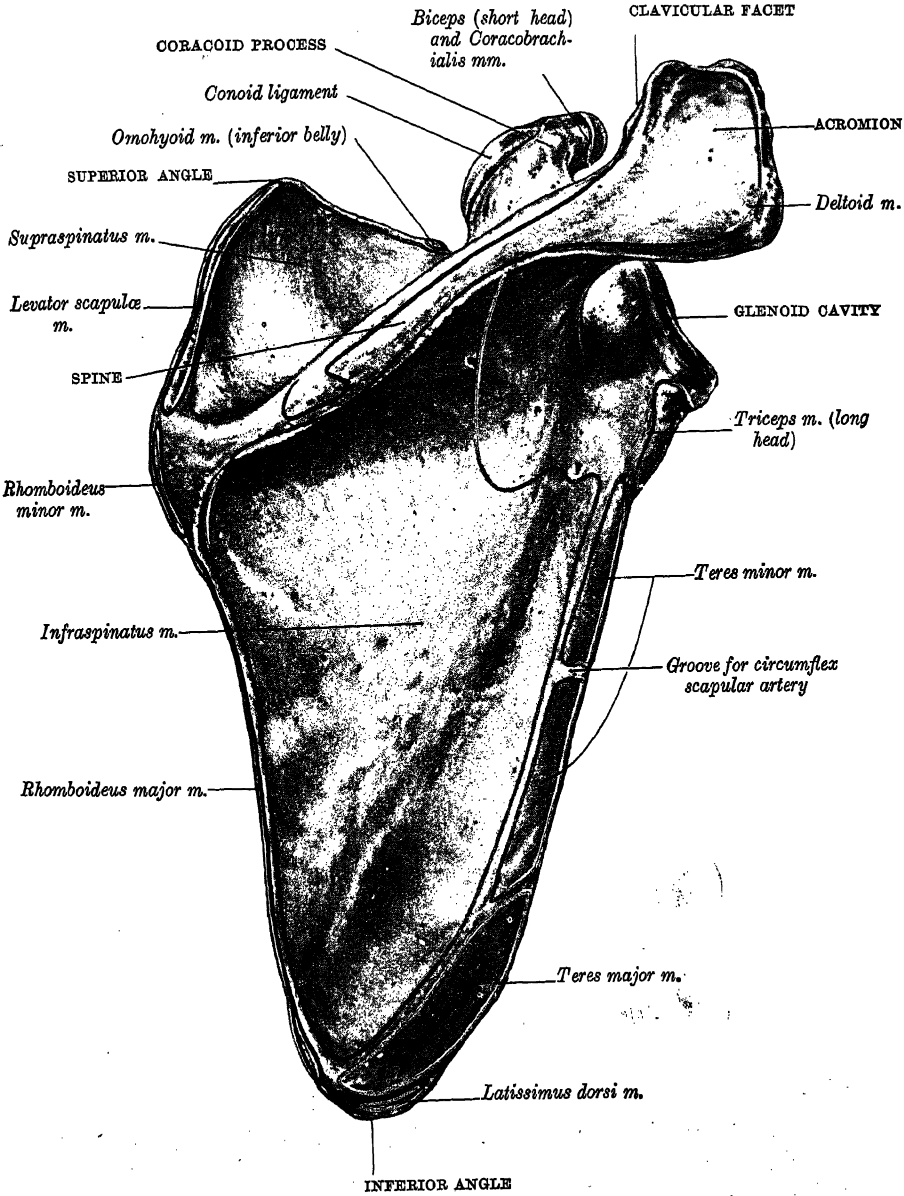
The *acromion* projects freely from the lateral end of the spine, with which it is continuous. Its long axis, however, does not coincide with that of the spine, but makes an angle with it of rather more than 90°. The lower border of the crest of the spine becomes continuous with the lateral border of the acromion at the *acromial angle*, which forms a subcutaneous, bony landmark. The medial border of the acromion is short and is marked anteriorly by a small, oval facet, directed upwards and medially, for articulation with the lateral end of the clavicle. The lateral border, tip and upper surface of the acromion can all be felt through the skin without difficulty. The *coracoid process* (fig. 397) springs from the upper border of the head of the scapula and is bent sharply so as to project forwards and slightly laterally. *When the arm is by the side, the coracoid process points almost straight forwards* and its slightly enlarged tip can be felt through the skin, although it is covered by the anterior fibres of the deltoid muscle. The supraglenoid tubercle marks the root of the coracoid process where it adjoins the upper part of the glenoid cavity. Another impression is placed on the dorsal aspect of the coracoid process at the point where it changes direction. This gives attachment to the conoid part of the coracoclavicular ligament, which will be mentioned again in connexion with the clavicle.

Particular features.—The *costal surface* gives origin to the subscapularis muscle (fig. 397), which arises from nearly the whole of this aspect including the grooved area immediately adjoining the lateral border and excluding the area adjoining the neck of the bone. Small intramuscular tendons are attached to the roughened ridges which subdivide this surface incompletely into a number of smooth areas. The anterior aspect of the neck is separated from the subscapularis muscle by a bursal protrusion of the synovial membrane of the shoulder-joint. Near the inferior angle a somewhat oval area gives insertion to the lower five or six digitations of the serratus anterior (fig. 397). The remainder of the muscle is inserted into a narrow strip along the ventral aspect of the medial border, which is wider above, where it receives the large first digitation. The rounded, longitudinal ridge near the lateral border corresponds to a localised thickening of the bone and provides a lever of the necessary strength to enable the serratus anterior to rotate the scapula forwards. In this movement the upper limb is raised from the side and carried above the head against the action of gravity, and it is this latter factor which calls for the provision of a substantial lever.

On the *dorsal surface*, the supraspinous fossa in its medial two-thirds gives origin to the supraspinatus, and its margins give attachment to the fascia which covers the muscle. The flattened strip adjoining the lateral border gives origin in its upper two-thirds to the teres minor muscle and is grooved, near its upper end, by the circumflex scapular vessels, which pass between the muscle and the bone as they enter the infraspinous fossa (fig. 398). The lower limit of the origin of the teres minor is indicated by an oblique ridge, which runs from the lateral border to the neighbourhood of the inferior angle and cuts off a somewhat oval area for the origin of the teres major muscle. The dorsal aspect of the inferior angle may give origin to a small slip which joins the deep surface of the latissimus dorsi. With the exception of an area near the neck of the bone, the rest of the infraspinous fossa, which is hollowed out laterally but convex medially, gives origin to the infraspinatus muscle. The strong infraspinatus fascia passes on to the teres minor and the teres major and sends fascial partitions between them to reach the bone along the ridges which mark the limits of their attachments.

The *lateral* (*axillary*) *border* separates the origin of the subscapularis from the origins of the teres minor and the teres major. These muscles project laterally beyond it, and together with the latissimus dorsi cover it so completely that it cannot be felt through the skin. The infraglenoid tubercle gives origin to the long head of the triceps muscle. The *medial* (*vertebral*) *border* is thin and often angled opposite the root of the spine. A narrow strip, extending from the superior angle to the root of the spine, gives insertion to the levator scapulæ muscle. Below this, and opposite the root of the spine, the rhomboideus minor

FIG. 398.—The right scapula. Dorsal aspect.



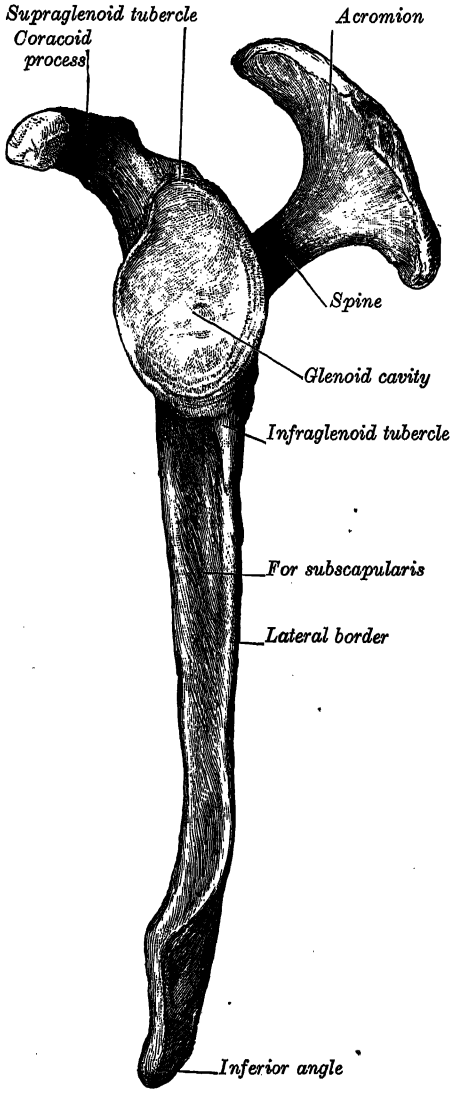
gains insertion. The remainder of the border provides insertion for the rhomboideus major, but the precise character of the insertion is unusual (p. 585). The attachment of the serratus anterior has been noted already (p. 334).

The *upper border* of the scapula is thin and sharp. Near the suprascapular notch it gives origin to the inferior belly of the omohyoid muscle, and the posterior limit of the notch gives attachment to the suprascapular ligament, which is sometimes ossified. The foramen

completed by the ligament transmits the suprascapular nerve to the supraspinous fossa, whereas the suprascapular (transverse scapular) vessels pass backwards above the ligament.

The *inferior angle* of the scapula is covered on its dorsal aspect by the upper border of the latissimus dorsi muscle, which frequently receives a small slip of origin from this part of the bone. The *superior angle* of the scapula is covered by the upper part of the trapezius muscle. The truncated *lateral angle* bears the *glenoid cavity*, the margins of which give attachment to the glenoidal labrum. Its surface is covered with a layer of hyaline articular cartilage, which is thinnest at the centre of the cavity and thickest at its periphery. Its anterior margin gives attachment to the glenohumeral ligaments (p. 457). When the arm is by the side the cavity is directed forwards, laterally and slightly upwards. When the arm is raised above the head it is directed almost straight upwards

FIG. 399.—The left scapula. Lateral aspect.



The *spine of the scapula* gives attachment by its upper and lower surfaces to the supra- and infraspinatus muscles, respectively. The flattened, triangular area at its root lies opposite the spine of the third thoracic vertebra and is covered by the tendon of the trapezius, a bursa intervening to enable the tendon to play over this part of the bone. The lower border of the crest gives origin to the posterior fibres of the deltoid muscle, which often produce an elongated tubercle in this situation. The upper border of the crest receives the insertion of the lower fibres of the trapezius, which often encroach on the dorsal or subcutaneous aspect of the crest, especially near the root of the spine.

The *acromion* is subcutaneous over its dorsal surface, being covered only by the skin and superficial fascia. The lateral border, which is thick and irregular, and the tip of the process, as far round as the clavicular facet, give origin to the middle fibres of the deltoid muscle. The medial aspect of the tip gives attachment, below the deltoid, to the lateral end of the coraco-acromial ligament. The articular capsule of the acromioclavicular joint is attached around the margins of the clavicular facet. Behind the facet, the medial border of the acromion gives insertion to the horizontal fibres of the trapezius muscle. The inferior aspect of the acromion is relatively smooth, and together with the coraco-acromial ligament and the coracoid process forms a protective arch over the shoulder-joint. The tendon of the supraspinatus passes below the overhanging acromion and is separated from it and from the deltoid muscle by the subacromial bursa.

The *coracoid process* lies below the clavicle at the junction of the lateral fourth with the rest of the bone and is connected to its under surface by the coraco-clavicular ligament. The attachment of the conoid part of the ligament has already been considered: the trapezoid part is attached to the upper aspect of the horizontal part of the process (fig. 397). The superior aspect of the process receives also the insertion of the pectoralis minor muscle. Its lateral border gives attachment to the wider, medial end of the coraco-acromial ligament and, below that, to the coracohumeral ligament. The enlarged tip of the process gives origin to the coracobrachialis, medially, and to the short head of the biceps, laterally. It is covered, in life, by the anterior fibres of the deltoid muscle and can be identified only on deep pressure through the lateral border of the infraclavicular fossa. It lies 2·5 cm. below the clavicle. The inferior aspect of the process is smooth and helps to complete the

coraco-acromial arch. The anterior aspect of the root is crossed by the tendon of the subscapularis, and its posterior aspect by the tendon of the supraspinatus muscle.

Structure.—The head, processes, and thickened parts of the scapula contain spongy substance; the rest consists of a thin layer of compact bone. The central part of the supraspinous fossa and the greater part of the infraspinous fossa are thin; occasionally the bone is wanting in these situations, the gaps being filled by fibrous tissue.

Ossification (fig. 400).—The scapula is ossified from eight or more centres: one for the body, two for the coracoid process, two for the acromion, one for the vertebral border, one for the inferior angle and one for the lower part of the rim of the glenoid cavity.

The centre for the body appears in the eighth week of intrauterine life, and spreads to form an irregular quadrilateral plate of bone, immediately behind the glenoid cavity. This

Fig. 400.—A plan of the ossification of the scapula.

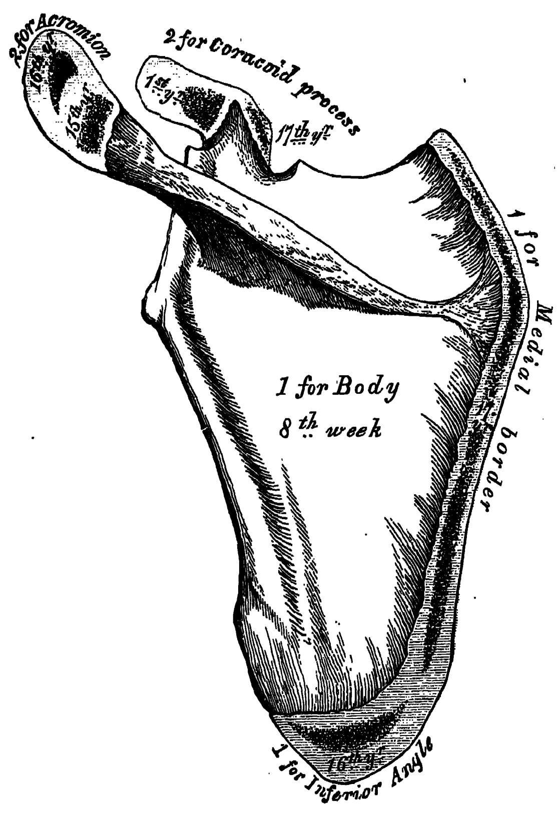


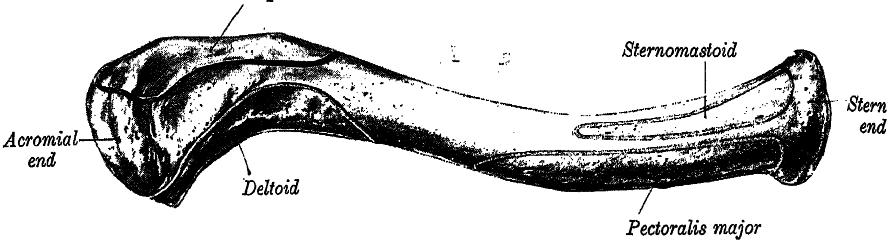
plate forms the chief part of the bone, and the spine grows backwards from it about the third month. At birth, the glenoid cavity, coracoid process, acromion, medial border, and inferior angle are cartilaginous. In the first year of life, ossification begins in the middle of the coracoid process, and this process joins the rest of the bone about the fifteenth year. Between the tenth and twentieth years ossification of the remaining parts takes place, usually in the following order: first, in the root of the coracoid process (subcoracoid centre); second, near the base of the acromion; third, in the inferior angle and contiguous part of the medial border; fourth, near the extremity of the acromion; fifth, in the medial border. The base of the acromion is formed by an extension from the spine; the rest of the acromion is ossified from two centres which unite, and then join the extension from the spine. The upper one-third of the glenoid cavity is ossified from the subcoracoid centre, which appears between the tenth and eleventh, and joins between the sixteenth and the eighteenth, years. Further, a horseshoe-shaped epiphyseal plate appears for the lower part of the glenoid cavity about puberty; thicker at its peripheral than at its central margin, it converts the flat glenoid fossa of the child into the gently concave fossa of the adult. The tip of the coracoid process frequently has a separate centre. These various epiphyses are joined to the bone by the twenty-fifth year.

THE CLAVICLE (figs. 401, 402)

General features.—The **clavicle**, though a long bone, differs from the other long bones in the body in not possessing a medullary cavity. It lies almost horizontally at the root of the neck and is *subcutaneous throughout its whole extent*. Its most important functions are: (1) to act as a prop which braces back the shoulder and enables the limb to swing clear of the trunk: and (2) to transmit a part of the weight of the limb to the axial skeleton, in this way diminishing the muscular effort required for that purpose. The lateral or *acromial end* of the bone is flattened and articulates with the medial side of the acromion, whereas the medial or *sternal end* is enlarged and articulates with the clavicular notch of the manubrium sterni. The *shaft* is gently curved and in shape resembles the italic letter *f*, being convex *forwards* in its medial portion and concave forwards in its lateral portion. The *inferior* aspect of the intermediate third is grooved in its long axis. The student is now in a position to refer a given clavicle correctly to its appropriate side of the body.

For purposes of description it is convenient to divide the shaft into its lateral one-third, which is flattened, and its medial two-thirds, which are cylindrical or prismoid in form.

FIG. 401.—The right clavicle. Viewed from above.



The **lateral one-third** of the shaft of the clavicle has a superior and an inferior surface, limited by an anterior and a posterior border. The *anterior border* is concave, thin and roughened and may be marked by a small tubercle termed the *deltoid tubercle*. The *posterior border*, also roughened for muscular attachments, is convex backwards. The *superior surface* is flattened; it is roughened near its margins but is smooth centrally, where it can be felt through the skin. The *lower surface* presents two obvious markings. Close to the posterior border, at the junction of the lateral one-fourth with the rest of the bone, a prominent tubercle gives attachment to the conoid part of the coracoclavicular ligament and is termed the *conoid tubercle*. From the lateral side of this tubercle a narrow, roughened strip runs forwards and laterally, reaching almost as far as the acromial end. This strip is termed the *trapezoid ridge* and gives attachment to the trapezoid part of the coracoclavicular ligament.

The **medial two-thirds** of the shaft of the clavicle usually possess four surfaces, but the inferior surface is often reduced to a mere ridge. The *anterior surface* is roughened over most of its extent but it is smooth and rounded at its lateral end, where it forms the upper boundary of the infraclavicular fossa. The *upper surface*, also, is roughened in its medial part and smooth at its lateral end. The *posterior surface* is smooth and featureless. The *inferior surface* is marked, near the sternal end, by a roughened impression, which is often depressed below the surface. This gives attachment to the costoclavicular ligament, which connects the clavicle to the upper surface of the first rib and helps to limit its range of movement. The lateral half of this surface shows a groove in the long axis of the bone.

The flattened *acromial end* of the clavicle presents a small oval articular facet, which articulates with the medial aspect of the acromion at the acromioclavicular joint. The facet is directed laterally and slightly downwards.

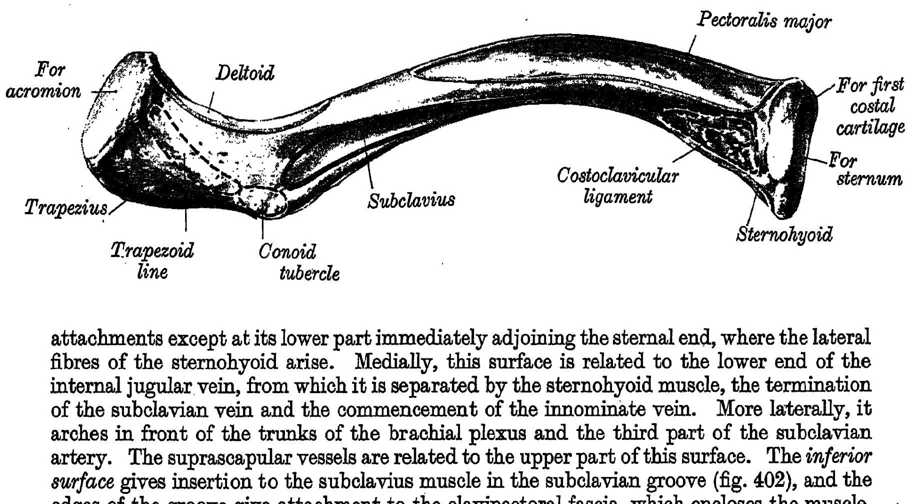
The *sternal end* of the clavicle is directed medially, and a little downwards and

forwards, to articulate with the clavicular notch of the manubrium sterni. The sternal surface is quadrangular (sometimes triangular) in form, and its uppermost part is slightly roughened for ligamentous attachments. Elsewhere, in a normal bone, the surface is smooth and articular and it is carried round on to the inferior surface for a short distance, where it articulates with the first costal cartilage. The sternal end of the clavicle projects upwards beyond the manubrium sterni and can be felt without difficulty in the lateral wall of the suprasternal fossa.

Particular features.—The *lateral one-third* of the shaft gives attachment to the deltoid muscle by its anterior border, and to the trapezius muscle by its posterior border. Both muscles encroach on the upper surface. The coracoclavicular ligament, attached to the conoid tubercle and the trapezoid ridge (fig. 402), transmits a large part of the weight of the upper limb to the clavicle. This weight is counteracted by the tonus of the trapezius muscle, which supports the lateral part of the bone. From the conoid tubercle the weight is transmitted through the medial two-thirds of the shaft to reach the axial skeleton. Fracture of the clavicle medial to the conoid tubercle interrupts the line of weight transmission, so that practically the whole weight of the limb has to be supported by the trapezius. The muscle is unable to meet the demand and the limb therefore drops on the affected side.

The *medial two-thirds* give attachment anteriorly to the clavicular head of the pectoralis major muscle, and, as a rule, the area is clearly indicated on the bone. The clavicular head of the sternomastoid arises from the medial half of the upper surface, but the marking on the bone is not very conspicuous. The smooth, posterior surface is devoid of muscular

FIG. 402.—The right clavicle. Viewed from below.



attachments except at its lower part immediately adjoining the sternal end, where the lateral fibres of the sternohyoid arise. Medially, this surface is related to the lower end of the internal jugular vein, from which it is separated by the sternohyoid muscle, the termination of the subclavian vein and the commencement of the innominate vein. More laterally, it arches in front of the trunks of the brachial plexus and the third part of the subclavian artery. The suprascapular vessels are related to the upper part of this surface. The *inferior surface* gives insertion to the subclavius muscle in the subclavian groove (fig. 402), and the edges of the groove give attachment to the clavipectoral fascia, which encloses the muscle. The posterior lip of the groove runs into the conoid tubercle and carries the fascia into continuity with the conoid ligament. A nutrient foramen is found in the lateral end of the groove, running in a lateral direction. The nutrient artery concerned is derived from the suprascapular (transverse scapular) artery. The impression for the costoclavicular ligament, which is very variable in its character, is separated from the sternal end by a short interval.

The margins of the articular facet at the *acromial end* give attachment to the articular capsule of the acromioclavicular joint.

The roughened, upper part of the *sternal end* provides attachment for the interclavicular ligament, the articular capsule and the articular disc of the sternoclavicular joint. The sternal surface, denuded of its articular cartilage, is rarely smooth and is usually irregular and somewhat pitted.

In a woman, the clavicle is shorter,* thinner, less curved and smoother than in a man. In women the acromial end is a little below the level of the sternal end; in men it is on a level with, or slightly higher than, the sternal end. In those who perform hard manual labour the clavicle is thicker and more curved, and its ridges for muscular attachment are better marked.

* F. G. Parsons (*Journal of Anatomy and Physiology*, vol. li.) gives the following as the average lengths of the clavicle in the male and female: male, left, 154 mm., right, 152 mm.; female, left, 139 mm., right, 138 mm.

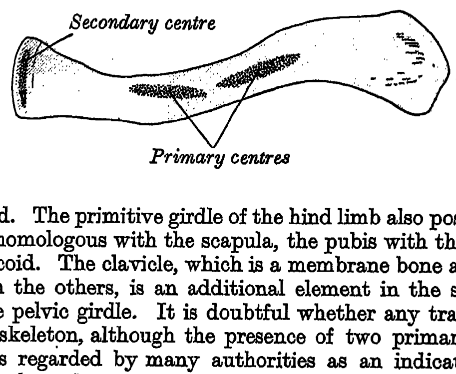
Structure.—The clavicle consists of spongy substance, enveloped by a layer of compact bone which is much thicker in the intermediate part of the bone than at the ends.

Ossification.—The clavicle begins to ossify before any other bone in the body, and is ossified from three centres. The shaft of the bone is ossified in membrane from two primary centres *—a medial and a lateral—which appear between the fifth and sixth weeks of intrauterine life, and fuse about the forty-fifth day ; a secondary centre for the sternal end appears about the eighteenth or twentieth year, and unites with the body of the bone about the twenty-fifth year. A secondary centre of ossification sometimes develops in the cartilage at the acromial end at about eighteen to twenty. The epiphysis so formed is always small and rudimentary and rapidly joins the rest of the bone.†

In a 14 mm. embryo the future clavicle is represented by a band of mesenchyme which extends from the acromion of the scapula to the tip of the first rib, and is continuous with the rudiment of the sternum. In this band a medial and a lateral mass of 'precartilage' is developed, and in the mesenchyme intervening between them the two centres for the body of the bone appear and soon fuse with each other. The sternal and acromial parts of the precartilaginous masses are converted into cartilage, and into this the ossification of the body of the bone extends.

The primitive reptilian shoulder girdle comprises a dorsal element—the scapula—and two ventral elements, of which the anterior (headward) is the precoracoid and the posterior

FIG. 403.—Diagram showing the three centres of ossification of the clavicle.



(caudal) is the coracoid. The primitive girdle of the hind limb also possesses three elements, of which the ilium is homologous with the scapula, the pubis with the precoracoid and the ischium with the coracoid. The clavicle, which is a membrane bone and therefore morphologically distinct from the others, is an additional element in the shoulder girdle but is not represented in the pelvic girdle. It is doubtful whether any trace of the precoracoid persists in the human skeleton, although the presence of two primary centres of ossification for the clavicle is regarded by many authorities as an indication that the human clavicle corresponds both to the precoracoid and to the clavicle in the reptilian shoulder-girdle.

The clavicle is absent in animals in which the forelimbs are used principally or entirely for progression, e.g. the ungulates and carnivores, but it is present and well developed in animals which use the limb for prehension, e.g. many rodents, the primates and man.

Applied Anatomy.—The clavicle is very frequently fractured. The most common cause is indirect violence, as the result of force applied to the hand or shoulder, and the bone then gives way at the junction of its lateral with its intermediate third, that is to say, at the junction of the two curves, for this is its weakest part. The deformity is mainly due to the weight of the arm acting upon the fragment when the prop-like action of the bone is gone, assisted by the muscles which pass from the thorax to the upper limb. The medial fragment, as a rule, is little displaced.

THE HUMERUS (figs. 404–409)

General features.—The **humerus** is the longest and largest bone of the upper limb. It comprises expanded upper and lower extremities and a more or less cylindrical shaft. The rounded head occupies the upper and medial part of the

* Mall, *American Journal of Anatomy*, vol. v., 1906 ; Fawcett, *Journal of Anatomy and Physiology*, vol. xlvii. ; Hanson, *Anatomical Record*, vol. xix. (number 6), 1920.

† T. Wingate Todd and J. D'Errico, jr., *American Journal of Anatomy*, vol. 41, 1928.

upper end of the bone. The lesser tuberosity projects from the front of the shaft, close to the head, and is limited on its lateral side by a well-marked groove. By examination of the head and the lesser tuberosity the student should be able to assign a given humerus correctly to its appropriate side of the body.

The **upper end** of the humerus consists of the head, and the greater and lesser tuberosities (tubercles).

The *head* of the humerus (figs. 404, 408) forms rather less than half a sphere, and its smooth surface is covered with hyaline articular cartilage in life and in the unmacerated specimen. When the arm is at rest by the side, it is directed medially, backwards and upwards to articulate with the glenoid cavity of the scapula. The humeral articular surface is much more extensive than the glenoid cavity, and only a portion of it is in contact with the cavity in any one position of the arm. The margin of the head is most distinct in its medial and lower part.

The *anatomical neck* of the humerus immediately adjoins the margin of the head and forms a slight constriction, which is least apparent in the neighbourhood of the tuberosities.

The *lesser tuberosity* (*tubercle*) is placed on the anterior aspect of the bone immediately beyond the anatomical neck, and shows a smooth, muscular impression on its upper part. Although thickly covered by muscle it can be felt through the skin. The lateral edge of the lesser tuberosity is sharp and forms the medial border of the bicipital groove.

The *greater tuberosity* occupies the lateral part of the upper end of the humerus and is *the most lateral bony point in the shoulder region.* It projects beyond the lateral border of the acromion and, covered by the thick, fleshy deltoid muscle, is responsible for the normal rounded contour of the shoulder. The portion of the tuberosity which adjoins the anatomical neck shows three flattened impressions for muscular attachments.

The *bicipital groove* (*intertubercular sulcus*) separates the two tuberosities and lodges the tendon of the long head of the biceps muscle.

The **shaft** of the humerus is almost cylindrical in its upper half but is triangular on section in its lower half, which is compressed in an anteroposterior direction. It presents three surfaces and three borders—which are not everywhere equally obvious.

The *anterior border* commences above on the front of the greater tuberosity and runs downwards almost to the lower end of the bone. Its upper third forms the lateral lip of the bicipital groove and is roughened for muscular attachments. The succeeding portion is also roughened and forms the anterior limit of the deltoid tuberosity, but the lower half of the border is smooth and rounded.

The *lateral border* is conspicuous at the lower end of the bone, where its sharp edge is roughened along its anterior aspect. In the middle and upper thirds of the bone the border is barely discernible to the inexperienced eye, but in a well-marked bone it can be traced upwards to the posterior surface of the greater tuberosity. About its middle the border is interrupted by a wide, shallow groove which crosses the bone obliquely, passing downwards and forwards from its posterior to its anterior surface. It is termed the *spiral groove* (radial groove).

The *medial border*, although rounded, can be identified without difficulty in the lower half of the shaft. A little below the middle of the bone it presents a roughened strip, and superiorly it becomes indistinct until it reappears as the medial lip of the bicipital groove. In this situation the border is again roughened and can be traced into the lesser tuberosity.

The *anterolateral surface* of the humerus lies between the anterior and the lateral borders. A little above its middle it is marked by a V-shaped roughened area which is termed the *deltoid tuberosity*. The limbs of the V are broad and behind the posterior limb the spiral groove runs downwards and fades away on the lower part of the surface.

The *anteromedial surface* is bounded by the anterior and the medial borders of the bone. Rather less than its upper third forms the rough floor of the bicipital groove, but the rest of the surface is smooth. A little below its middle the nutrient foramen, which is directed downwards, opens close to the medial border.

The *posterior surface* lies between the medial and the lateral borders and is the most extensive surface of the three. Its upper third is crossed by a faint ridge, sometimes roughened, which runs obliquely downwards and laterally. The middle

Fig. 404.—The left humerus. Anterior aspect.

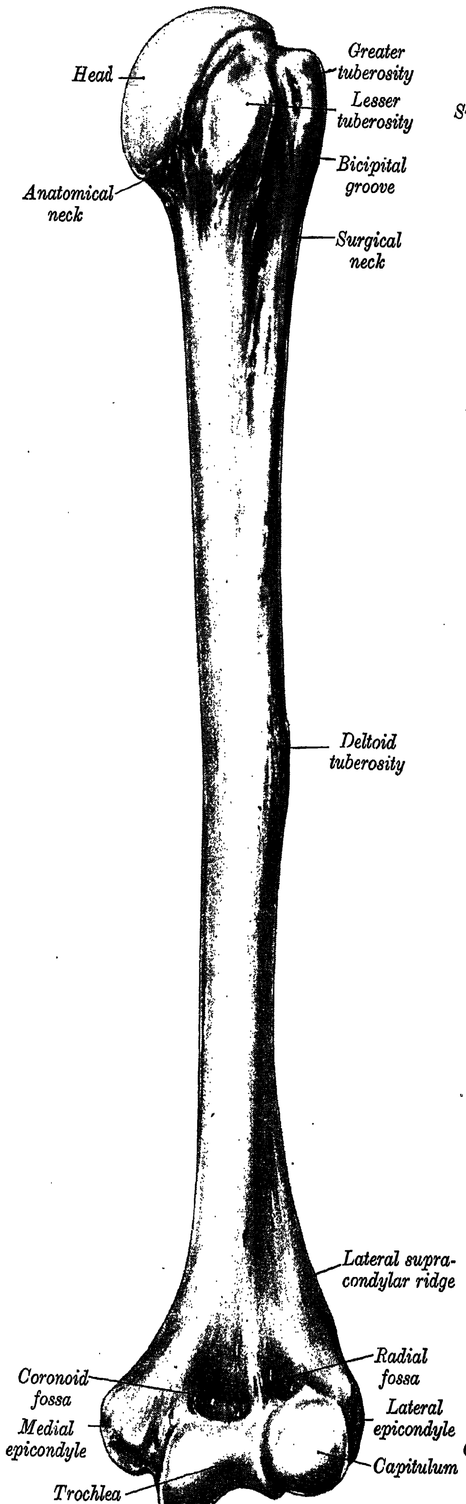
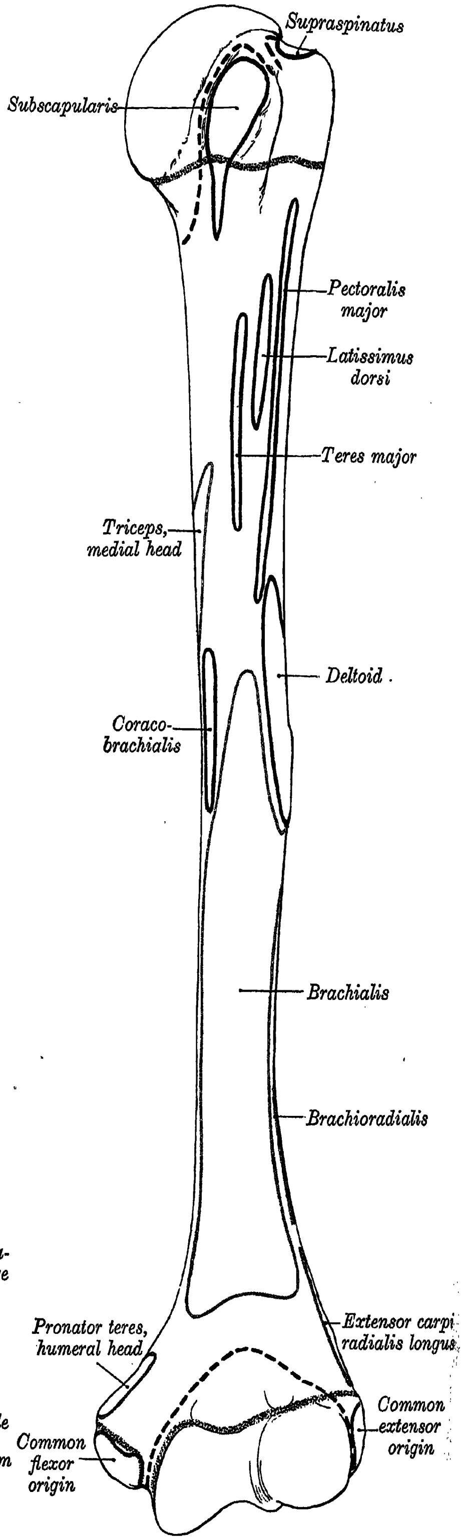


Fig. 405.—Key to fig. 404.



The interrupted lines indicate the attachment of the capsular ligaments; the stippled lines mark the position of the epiphyseal lines.

third is crossed by the commencement of the spiral groove. Rather more than the lower third forms an extensive, flattened surface, which widens considerably below.

The **lower end** of the humerus (figs. 404, 409) is expanded transversely, and presents articular and non-articular portions.

The *articular portion* takes part with the radius and the ulna in the formation of the elbow-joint. It is divided by a faint groove into a lateral, convex surface, termed the capitulum, and a medial, pulley-shaped surface, termed the trochlea.

The *capitulum* is a rounded, convex projection, considerably less than half a sphere, which covers the anterior and inferior surfaces of the lower end of the humerus but does not extend on to its posterior surface. It articulates with the disc-like head of the radius, which lies in contact with its inferior surface in full extension of the elbow but moves on to its anterior surface when the joint is flexed.

The *trochlea* is a pulley-shaped surface, which covers the anterior, inferior and posterior surfaces of the lower end of the humerus. On its lateral side it is separated from the capitulum by a faint groove, but its medial margin is salient and projects downwards beyond the rest of the bone. The trochlea articulates with the trochlear (semilunar) notch of the ulna. When the elbow is extended the inferior and posterior aspects of the trochlea are in contact with the ulna, but, as the joint is flexed, the trochlear notch rolls forwards on to the anterior aspect and the posterior aspect is then left uncovered. The downward projection of the medial edge of the trochlea is the principal factor in determining the angulation which is present between the long axis of the humerus and the long axis of the supinated forearm when the elbow is extended. The angle, which is of approximately 170°, is open to the lateral side and is termed the 'carrying angle' (p. 467). Owing to the existence of this angulation, the ulnar or medial border of the supinated and extended forearm cannot be brought into contact with the lateral surface of the thigh, when the arm is by the side.

The *non-articular part* of the lower end of the humerus includes the medial and lateral epicondyles together with the olecranon, coronoid and radial fossæ.

The *medial epicondyle* forms a conspicuous, blunt projection on the medial side of the lower end of the humerus. It is subcutaneous and can easily be identified through the skin. Its posterior surface is smooth and is crossed by the ulnar nerve, as it runs down into the forearm. In this situation the nerve can be felt and rolled against the bone. If the pressure exerted is sufficient, sensations are aroused identical with those produced by a knock on the 'funny bone,' when the nerve is jarred against the epicondyle. The lower part of the anterior surface of the medial epicondyle shows an impression which gives attachment to the superficial group of the flexor muscles of the forearm.

The *lateral epicondyle* occupies the lateral part of the non-articular portion of the lower end of the humerus; but does not project laterally beyond the lateral border. Its lateral and anterior surfaces show a well-marked impression, which gives origin to the superficial group of the extensor muscles of the forearm. Its posterior surface, which is very slightly convex, can easily be felt through the skin at the back of the elbow (p. 348). The lateral border of the humerus terminates at the lateral epicondyle, and its lower portion is termed the *lateral supracondylar ridge*. The medial border of the humerus terminates below at the medial epicondyle, and its lower portion is termed the *medial supracondylar ridge*.

A deep hollow is situated on the posterior surface of the lower end of the humerus, immediately above the trochlea. It is termed the *olecranon fossa*, on account of the fact that it lodges the tip of the olecranon of the ulna when the elbow is extended. The floor of the fossa is always thin and may be partially deficient. A similar but smaller hollow lies immediately above the trochlea on the anterior surface of the lower end of the humerus and is termed the *coronoid fossa*. It provides room for the anterior margin of the coronoid process of the ulna during flexion of the elbow. A very slight depression lies above the capitulum on the lateral side of the coronoid fossa. It is termed the *radial fossa*, since it is related to the margin of the head of the radius in full flexion of the elbow.

In lower mammals the long axes of the upper and lower articular surfaces of the humerus make an angle with each other of little more than 90°. In man, however,

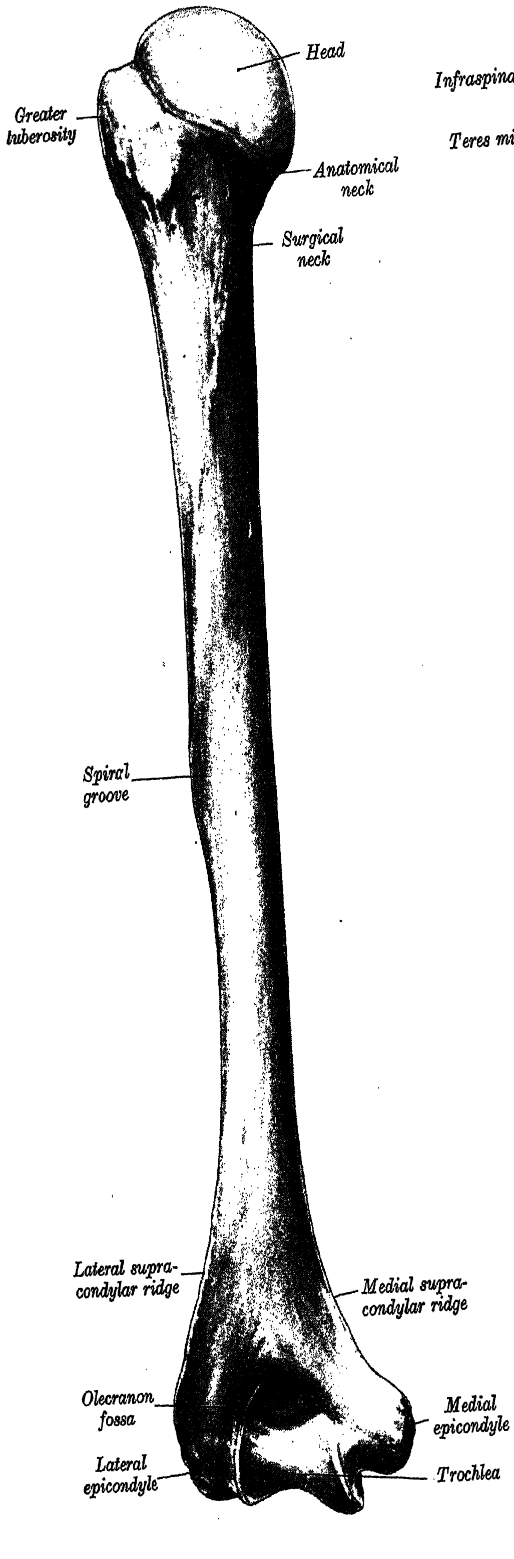


FIG. 406.—The left humerus. Posterior aspect.

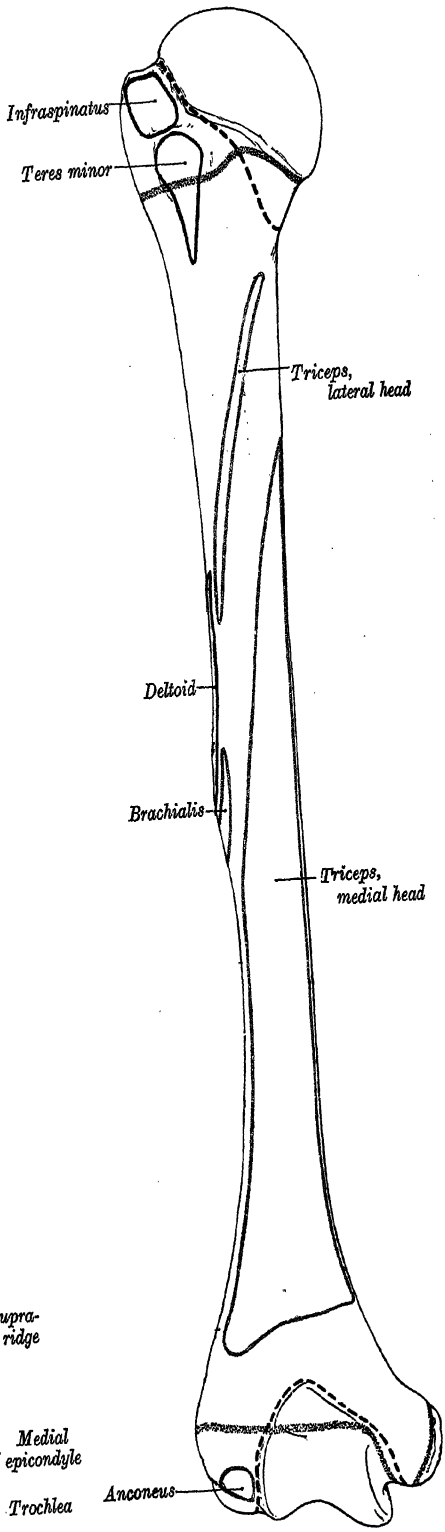
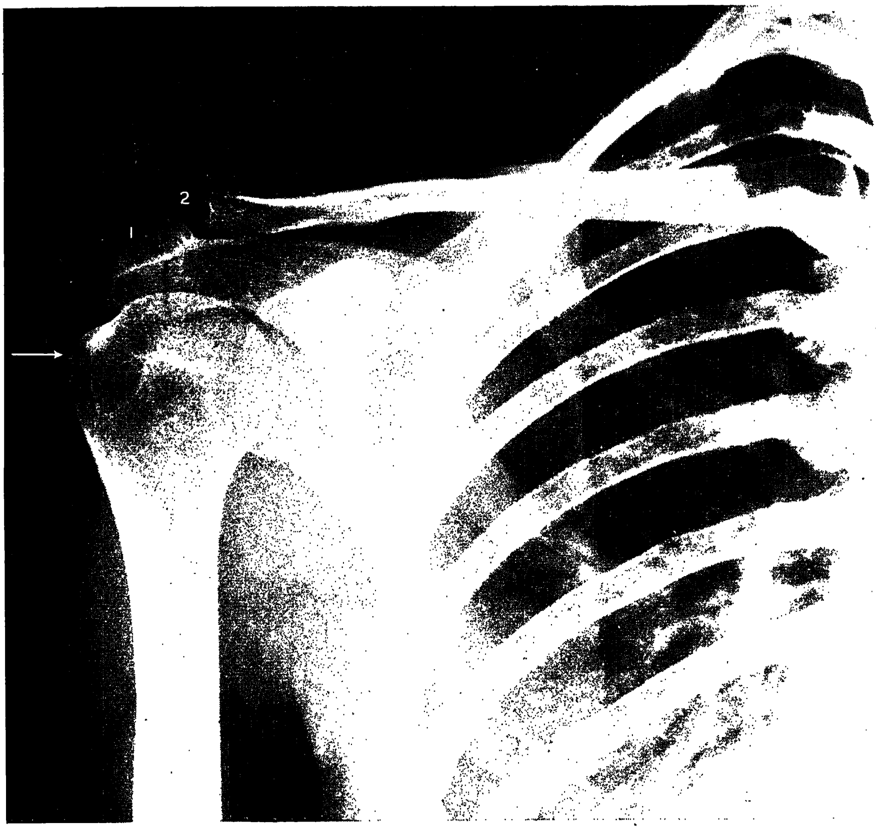


FIG. 407.—Key to fig. 406.

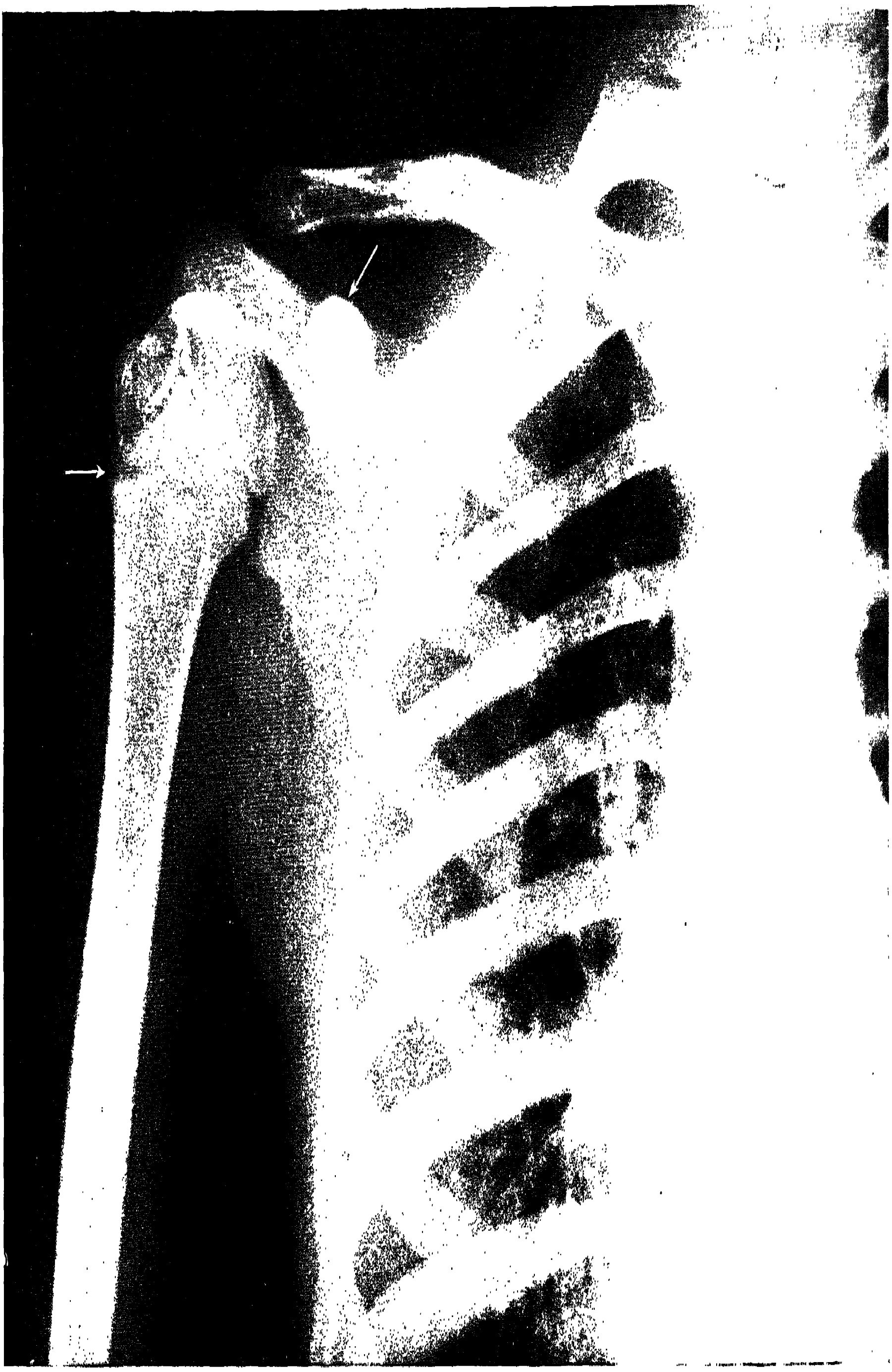
The interrupted lines indicate the attachment of the capsular ligaments; the stippled lines mark the position of the epiphyseal lines.

PLATE III



Radiograph of an adult shoulder. 1 = acromion ; 2 = acromio-clavicular joint. The lower arrow indicates the inferior angle of the scapula, the upper arrow the greater tuberosity. Note that the shadow of the head of the humerus overlaps the shadow of the acromial angle and a part of the glenoid cavity.

PLATE IV



Radiograph of the shoulder region of a child aged 6 years. The upper arrow indicates the coracoid process; the lower arrow indicates the epiphyseal line. Note that the upper end of the diaphysis is conical and projects into the centre of the epiphysis. The centres for the head of the humerus and the tuberosities have fused to form a single epiphysis.

the upper end of the humerus appears to have been rotated laterally, so that the angle between the two axes has been increased to about 164°. This angulation is referred to as the angle of 'humeral torsion.' It is greater in men than women, in adults than children, and in higher races than in lower races and anthropoids. The significance of the torsion of the humerus has not yet been explained in a satisfactory manner.

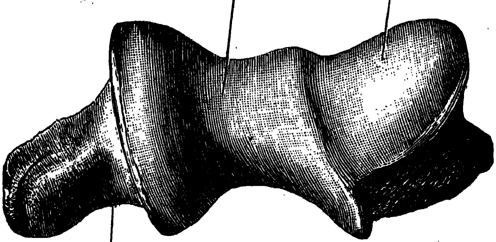
Particular features.—The cartilage which covers the *head* of the humerus is thickest at its centre and becomes thinner towards the circumference.

The *anatomical neck* gives attachment to the capsular ligament of the shoulder-joint (figs. 405, 407), except at the upper end of the bicipital groove, where a deficiency exists to allow the long tendon of the biceps to emerge from the joint. On the medial side, however, the attachment extends downwards for 1 cm. or more on to the shaft of the bone.

The *lesser tuberosity* gives insertion to the subscapularis muscle (fig. 405) and its sharp lateral margin gives attachment to the medial end of the transverse ligament of the shoulder-joint.

The *greater tuberosity* presents three muscular impressions. The uppermost receives the insertion of supraspinatus; the middle impression gives insertion to the infraspinatus; while the lowermost, which is placed on the posterior surface of the tuberosity, gives insertion to the teres minor muscle (fig. 407). The projecting lateral surface of the tuberosity presents numerous vascular foramina and is covered by the deltoid muscle. A part of the subacromial bursa may cover the upper part of this area and separate it from the muscle.

FIG. 408.—The lower end of the left humerus. Inferior aspect.



The *bicipital groove* lodges the long tendon of the biceps, its accompanying synovial sheath, and an ascending branch from the anterior circumflex humeral artery. The rough, lateral lip of the groove gives insertion to the bilaminar tendon of the pectoralis major; its floor receives the tendon of the latissimus dorsi; and its medial lip, the tendon of the teres major. The insertion of the pectoralis major extends to a lower level than the insertion of the teres major, while the insertion of the latissimus dorsi is the least extensive of the three. Below the bicipital groove the anteromedial surface of the humerus is devoid of muscular attachment over a small area, but its lower half gives origin to the medial portion of the brachialis muscle (fig. 405). The roughened strip on the middle of the medial border of the bone gives insertion to the coracobrachialis muscle. Close to the lowest part of the medial supracondylar ridge this surface gives origin over a narrow area to the superficial head of the pronator teres; and the ridge itself gives attachment to the medial intermuscular septum of the arm.

The oblique ridge which crosses the upper part of the *posterior surface* gives origin to the lateral head of the triceps. Above this muscle the circumflex (axillary) nerve and the posterior circumflex humeral vessels wind round this aspect of the bone under cover of the deltoid muscle. Below and medial to the origin of the lateral head of the triceps, the spiral groove, containing the radial nerve and the profunda vessels, runs downwards and laterally to gain the anterolateral surface of the shaft. The area for the origin of the fleshy medial head of the triceps includes a very large part of the posterior surface of the bone. It covers an elongated triangular area, the apex of which is placed on the medial part of the posterior surface above the level of the lower limit of the insertion of teres major. The area widens below and covers the whole surface almost down to the lower end of the bone (fig. 407).

The *anterolateral surface* of the humerus is smooth and featureless in its upper part, which is covered by the deltoid muscle. About, or a little above, the middle of this surface the deltoid muscle is inserted into the deltoid tuberosity, and below that level the surface

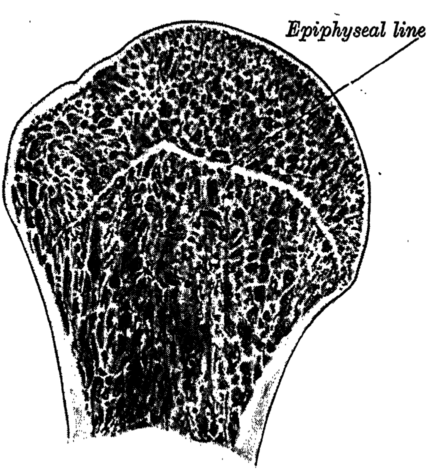
gives origin to the lateral fibres of the brachialis, which extend upwards into the floor of the lower end of the spiral groove (fig. 407). The roughened anterior aspect of the lateral supracondylar ridge gives origin by its upper two-thirds to the brachioradialis and by its lower third to the extensor carpi radialis longus. Behind these muscles the ridge gives attachment to the lateral intermuscular septum of the arm.

The *articular portion of the lower end* of the humerus is curved forwards, so that its anterior and posterior surfaces lie in front of the corresponding surfaces of the shaft. The groove of the trochlea winds backwards and laterally, as it is traced from the anterior to the posterior surface of the bone, and it is wider, deeper and more symmetrical posteriorly. Anteriorly, the medial flange of the pulley is much longer than the lateral, and the surface adjoining its projecting medial margin is convex to accommodate itself to the medial part of the upper surface of the coronoid process of the ulna.

The *capsular ligament of the elbow-joint* extends for some distance beyond the articular surface for its attachments to the humerus. Anteriorly it passes to the upper limits of the radial and coronoid fossæ, so that both these bony depressions are intracapsular and therefore lined with synovial membrane. Medially it is attached to the medial non-articular aspect of the projecting lip of the trochlea and to the root of the medial epicondyle. Posteriorly it ascends to, or almost to, the upper margin of the olecranon fossa, which is therefore intracapsular and covered with synovial membrane. Laterally it skirts the lateral borders of the trochlea and capitulum, lying medial to the lateral epicondyle.

The muscular impression on the *medial epicondyle* gives attachment to the common origin of the superficial group of flexor muscles. They arise from the epiphysis for the epicondyle, but are entirely outside the articular capsule of the elbow-joint. The impression on the *lateral epicondyle* gives attachment to the common origin of the superficial group of extensor muscles of the forearm. These arise from the lateral side of the lower humeral epiphysis, and, like the flexors, are situated outside the articular capsule. A small area on the posterior surface of the lateral epicondyle gives origin to the anconeus. The medial epicondyle is directed backwards a little at its extremity, whereas the lateral epicondyle shows a slight trend in the opposite direction.

FIG. 409.—A longitudinal section through the head of the right humerus.



It should be observed that when the humerus is at rest by the side the medial epicondyle lies on a plane which is posterior to the plane of the lateral epicondyle, so that the bone appears to be rotated medially. In this position the head of the humerus is directed almost equally backwards and medially, and the posterior surface of the shaft looks laterally as well as backwards. This position of the bone must be kept in mind when the movements of the arm and forearm are considered (pp. 460 and 467).

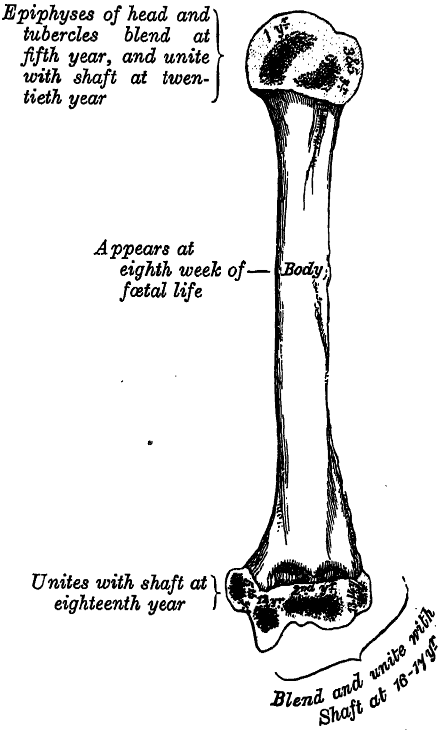
A hook-shaped process of bone, termed the *supracondylar process*, varying from 2 mm. to 20 mm. in length, is occasionally found projecting from the anteromedial surface of the shaft of the humerus, about 5 cm. above the medial epicondyle. It is curved downwards and forwards, and its pointed end is connected to the medial border, just above the epicondyle, by a fibrous band which gives origin to a portion of the pronator teres ; the foramen completed by this fibrous band usually transmits the median nerve and brachial artery. Sometimes the nerve alone is transmitted through it, or the nerve may be accompanied by the ulnar artery, in cases of high division of the brachial artery. A groove, which lodges the artery and nerve, is usually found behind the process. This foramen is the homologue of the supracondylar foramen found in many animals, and probably serves in them to protect the nerve and artery from compression during the contraction of the muscles in this region.

Structure.—The ends of the humerus consist of spongy substance, covered with a thin layer of compact bone (fig. 409) ; the shaft is a cylinder of compact bone, thicker at the centre than towards the extremities. A large medullary canal extends throughout its length.

Ossification (figs. 405, 410).—The humerus is ossified from eight centres—one for each of the following parts : the shaft, the head, the greater tuberosity, the lesser tuberosity, the capitulum and lateral part of the trochlea,

the medial part of the trochlea, and one for each epicondyle. The centre for the shaft appears near its middle in the eighth week of intrauterine life, and gradually extends towards the ends, which at birth are cartilaginous. During the first year, occasionally before birth, ossification begins in the head, during the third year in the greater tuberosity, and during the fifth in the lesser tuberosity. By the sixth year the centres for the head and tuberosities have joined to form a single large epiphysis, which is hollowed out on its inferior surface (fig. 409) to adapt it to the somewhat conical upper end of the diaphysis. It fuses with the shaft of the humerus about the twentieth year. The lower end is ossified as follows. At the end of the second year ossification begins in the capitulum and extends medially to form the chief part of the articular surface; the centre for the medial part of the trochlea appears about the twelfth year. Ossification begins in the medial epicondyle about the fifth year, and in the lateral about the thirteenth or fourteenth year. The centre for the lateral epicondyle fuses with those for the trochlea and capitulum (fig. 410), and the large epiphysis thus formed unites with the shaft about the sixteenth or seventeenth year; the centre for the medial epicondyle forms a separate epiphysis, which is entirely extra-capsular (fig. 410), and unites with the shaft about the eighteenth year.

Fig. 410.—A plan of the ossification of the humerus.



Applied Anatomy.—The upper epiphysis of the humerus, though the first to ossify, is the last to join the shaft, and the length of the bone is due mainly to growth from the upper epiphyseal plate. Hence, in cases of amputation through the arm in young subjects, the humerus continues to grow considerably, and the lower end of the bone, which immediately after the operation was covered with a thick cushion of soft tissue, begins to project, thinning the soft parts and rendering the stump conical. This may necessitate the removal of more bone, and even after this operation a recurrence of the conical stump may take place.

Fractures of the humerus are common. This bone is fractured by muscular action probably more frequently than any other long bone; it is usually the shaft of the bone, just below the insertion of the deltoid, which is thus broken, and the accident has been known to happen from throwing a stone or a hand-grenade. Fracture of the surgical neck of the bone is not uncommon; impaction may occur, or the upper end of the lower fragment may be displaced into the axilla and damage the vessels or nerves. Separation of the upper epiphysis sometimes occurs in the young subject, and is marked by a characteristic deformity, the upper end of the diaphysis projecting abruptly at the front of the shoulder and a short distance below the coracoid process. In fractures of the upper end of the humerus, extension with the arm in the abducted position is necessary, in order that, should ankylosis take place, the mobility of the scapula may be brought into full use. In fractures of the shaft of the humerus the lesion may take place at any point, but appears to be more common in the lower part of the bone than the upper. The points of interest in connexion with these fractures are: (1) that the radial nerve may be injured as it lies in the spiral groove, or may become involved during the process of repair; and (2) the frequency of non-union, which is believed to be more common in the humerus than in any other bone. The non-union is in some measure due to the difficulty in fixing the bone, since the upper end articulates with the movable scapula, and the shaft lies by the chest-wall, which moves with each respiration. Again, muscle is attached to the entire circumference of the bone and is liable to get between the fragments, should there be any overlapping of the broken ends. The circumflex (axillary) nerve may be injured by fractures of the upper end of the bone and the ulnar nerve by fracture of the medial epicondyle. In fractures of the lower end it is important to distinguish between those that involve the elbow-joint and those that do not; the former are always serious, as they may lead to impairment of the mobility of the joint; they include the T-shaped fracture and

oblique fractures which involve the articular surface. Those which do not involve the joint are the transverse fracture above the epicondyles, and the so-called epitrochlear fracture, where the tip of the medial epicondyle is broken off, generally by direct violence.

THE RADIUS (figs. 411–414)

General features.—The **radius** is the lateral bone of the forearm. It is a long bone, prismoid in form and gently curved in its long axis. The upper and lower ends are both expanded, but the lower end is much the wider of the two. The shaft increases in breadth rapidly towards the lower end, is convex to the lateral side and is concave forwards in its lower part. Examination of the shaft, therefore, will enable a given radius to be assigned correctly to its appropriate side of the body.

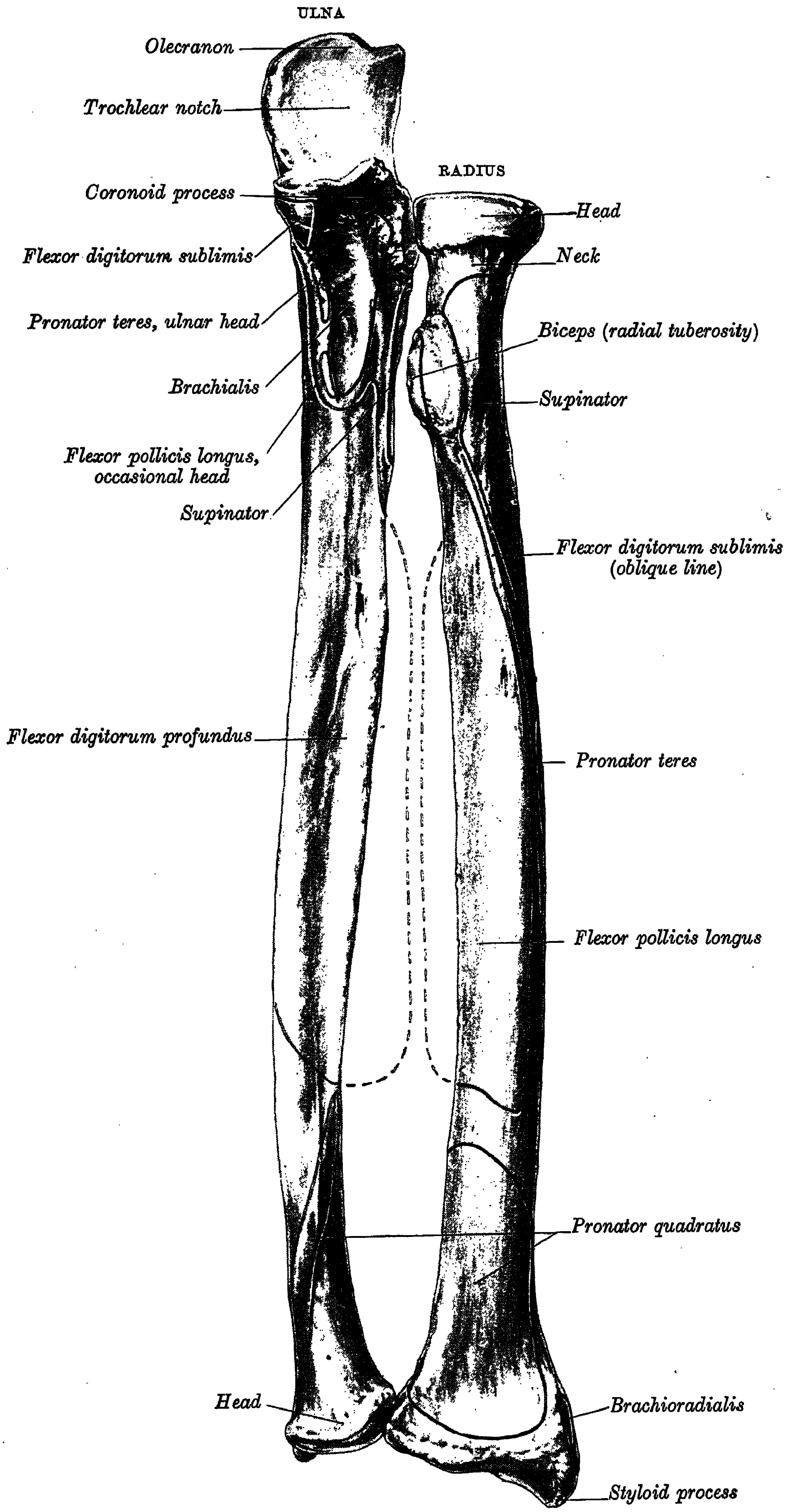
The upper end of the radius includes the head, the neck and the tuberosity. The **head** is disc-shaped and its upper surface is hollowed out to form a shallow cup for articulation with the capitulum of the humerus. The *articular circumference* of the head is smooth and is deepest on the medial side, where it articulates with the radial notch of the ulna. Its posterior surface can be felt through the skin, as it lies at the bottom of a small depression which is visible in the living subject on the lateral side of the posterior surface of the extended elbow. The *neck* of the radius is the constricted part immediately below the head, and is overhung by it, especially on the lateral side. The *tuberosity* of the radius is placed below the medial part of the neck. Its posterior part is roughened but its anterior part is usually smooth.

The **shaft** of the radius is narrow above but widens rapidly towards the lower end. As already stated, it is gently curved with the convexity directed to the lateral side. On transverse section it is triangular in outline, but only one of its three borders is sharp and easy to identify. The *interosseous border* is a salient crest, except at its upper end, where it approaches the lower part of the tuberosity. At its lower end it forms the posterior margin of a small, elongated, triangular area, which constitutes an additional—medial—surface for this end of the bone. In its lower three-fourths this border gives attachment to the interosseous membrane, which connects the opposed borders of the two bones of the forearm. The *anterior border* can be recognised without difficulty at its upper and lower ends, but it is rounded and indefinite in the intervening region. It commences just below the anterolateral part of the tuberosity and runs downwards with an inclination towards the lateral side. This part is often described as the *anterior oblique line* of the radius. The lower part of the anterior border forms a sharp crest along the lateral margin of the anterior surface, and can be recognised easily through the skin. The *posterior border* is clearly defined in its middle third only. Above, it runs obliquely upwards and medially towards the postero-inferior part of the tuberosity. Below, it forms a rounded ridge which is difficult to trace.

The *anterior surface* lies between the anterior and the interosseous borders. It is slightly concave from side to side and curves forwards at its lower end. A little above its middle it presents a nutrient foramen, which is directed upwards. The *posterior surface*, which is bounded by the interosseous and the posterior borders, is generally flat but may be slightly hollowed out in its upper part. The *lateral surface* is gently convex in all directions. Above, owing to the obliquity of the upper parts of the anterior and posterior borders, it encroaches on the anterior and posterior aspects of the bone, and this widened portion is usually slightly roughened. A finely irregular, rough surface occupies an oval area near the middle of the shaft, but below this the surface of the bone is smooth and featureless.

The **lower end** is the widest part of the radius, and is four-sided on transverse section. Its *lateral surface* is slightly rough and projects downwards beyond the rest of the bone to form the *styloid process*. This projection can be felt through the skin, when the tendons which conceal it in the living body are relaxed. The *inferior surface* of the lower end (fig. 417) is smooth and takes part in the formation of the wrist-joint. This articular surface is divided by a faint ridge into

FIG. 411.—The bones of the left forearm. Anterior aspect.



Ossification (figs. 413, 414).—The radius is ossified from three centres: one for the shaft, and one for each end. That for the shaft appears near the middle in the eighth week of intrauterine life. About the close of the second year, ossification begins in the lower end; and at the fifth year, in the upper end. The upper epiphysis fuses with the shaft at the age of seventeen or eighteen years, the lower about the age of twenty. An additional centre sometimes appears in the radial tuberosity about the fourteenth or fifteenth year.

Fig. 413.—A plan of the ossification of the radius. From three centres.

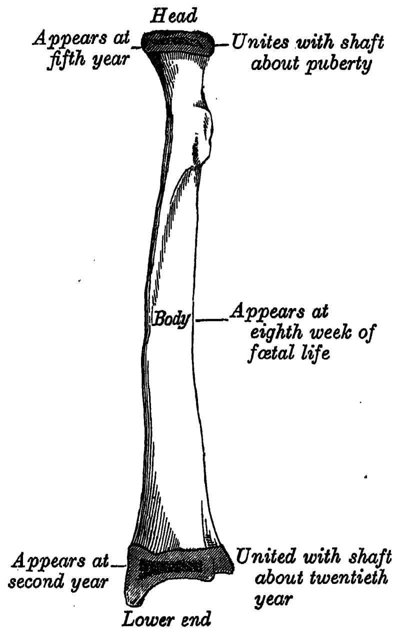
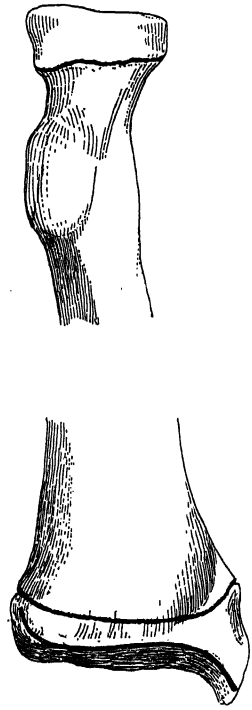


Fig. 414.—The epiphyseal lines of the left radius in a young adult. Anterior aspect.



The line of attachment of the articular capsule of the wrist-joint is in blue.

THE ULNA (figs. 411, 412, 415)

General features.—The **ulna** is the medial bone of the forearm and is parallel with the radius when the forearm is supine. The upper end is thick, strong and hook-like (fig. 415), the concavity of the hook being directed forwards. The lateral border of the shaft is a thin, sharp crest. This information is sufficient to enable the student to refer a given ulna correctly to its appropriate side of the body. The bone diminishes in size from its upper to its lower end, which bears a small, rounded enlargement termed the head of the ulna. The shaft is triangular on section, and no difficulty will be experienced in determining its three surfaces and their limiting borders.

The bone is not perfectly straight, and shows a slight but appreciable double curve. Throughout its whole length it forms a gentle curve, the convexity of which is directed backwards. In addition, the upper half or more shows a slight curvature to the lateral side, and the lower half or less a similar curvature in the opposite direction.

The **upper end** of the ulna (fig. 415) displays two substantial processes, named

PLATE V

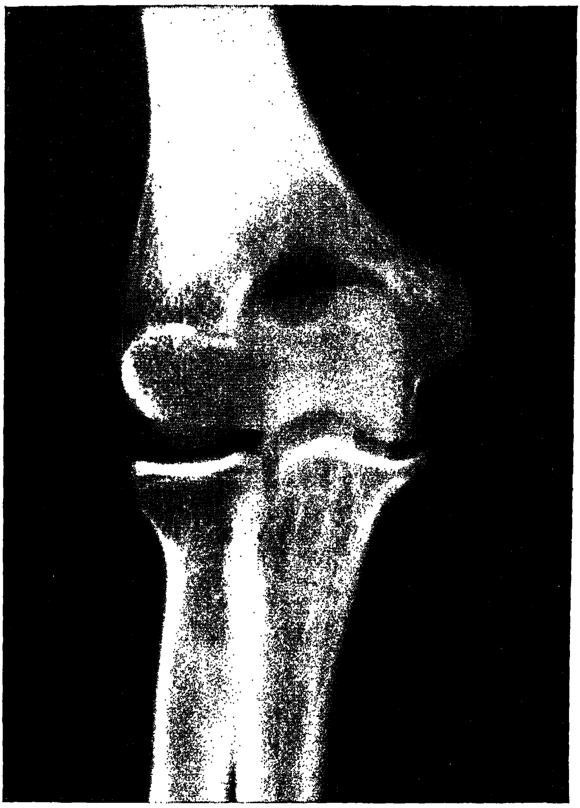


FIG. 1.—Radiograph of adult elbow. Frontal view. The shadow of the olecranon extends upwards to the olecranon fossa and obscures the outline of the trochlea. The gap between the humerus and the bones of the forearm is occupied by the articular cartilage of the bones concerned.

FIG. 2.—Radiograph of the elbow of a child aged 11 years. Frontal view. The upper epiphysis of the radius, the epiphysis for the medial epicondyle, and the centre for the capitulum and lateral part of the trochlea can be recognised without difficulty.

PLATE VI

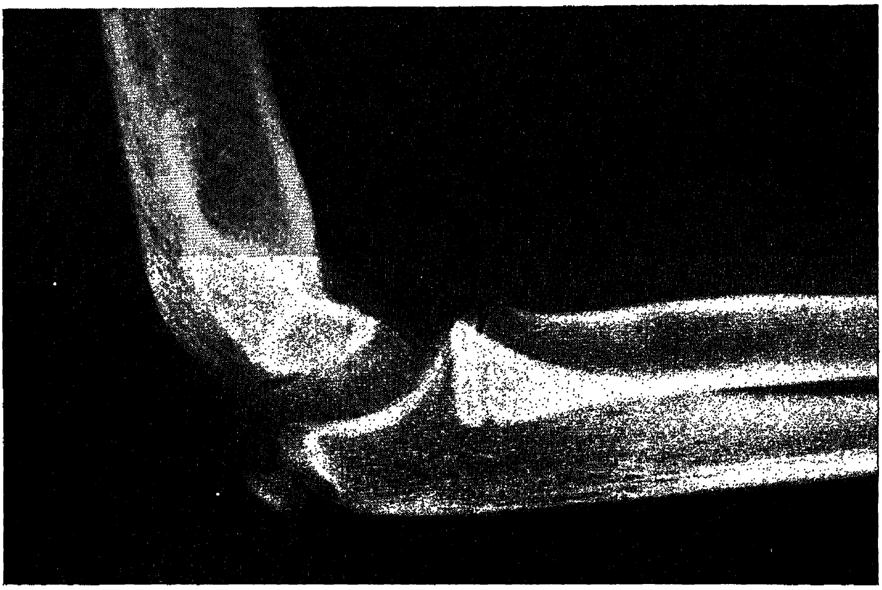


FIG. 1.—Radiograph of the elbow of a child aged 10 years. Lateral view. The upper epiphysis of the radius, the olecranon epiphysis and the centre for the capitulum and the lateral part of the trochlea can be recognised without difficulty.

FIG. 2.—Radiograph of an adult hand.

the olecranon and the coronoid process, and two articular areas, termed the trochlear (semilunar) and radial notches, which articulate, respectively, with the humerus and the radius.

The *olecranon* is the uppermost part of the bone. It is bent forwards at its summit to form a prominent beak, which is received into the olecranon fossa of the humerus when the forearm is extended. Its posterior surface, which is smooth and triangular in outline, can easily be felt through the skin, and its upper border forms the point of the elbow. The anterior surface is smooth and articular, and forms the upper part of the trochlear (semilunar) notch. The base of the olecranon is constricted where it joins the shaft, and this is the narrowest part of the upper end of the ulna.

The *coronoid process* forms a bracket-like projection from the front of the bone immediately below the olecranon. Its upper surface forms the lower part of the trochlear (semilunar) notch and is therefore smooth and articular. The upper part of the lateral surface presents the shallow *radial notch* for articulation with the side of the head of the radius, and the bone below it is hollowed out to make room for the tuberosity of the radius during the movements of pronation and supination. The anterior surface of the process is triangular in shape and bears on its lower part the rough *tuberosity of the ulna*. The medial border of the process is sharp and bears a small, but prominent, tubercle at its upper end.

The *trochlear* (*semilunar*) *notch* articulates with the trochlea of the humerus and is shaped accordingly. It is formed by the anterior surface of the olecranon and the superior surface of the coronoid process. The bone is constricted at the junction between these two areas, and they may be separated completely by a narrow, roughened strip. A smooth ridge, which corresponds to the groove of the trochlea, divides the notch into a larger, medial, and a smaller, lateral part. The medial part conforms to the large flange of the trochlea of the humerus.

The *radial notch* (fig. 415) is an oblong, articular depression on the upper part of the lateral aspect of the coronoid process. It articulates with the articular circumference of the head of the radius, and is separated from the lateral part of the trochlear notch by a smooth ridge.

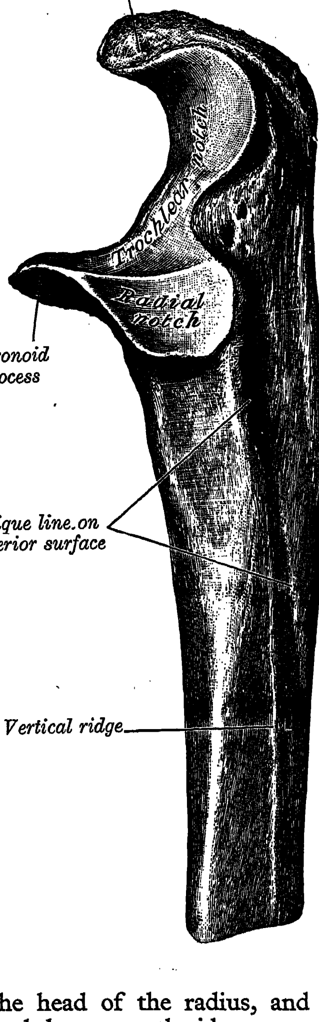
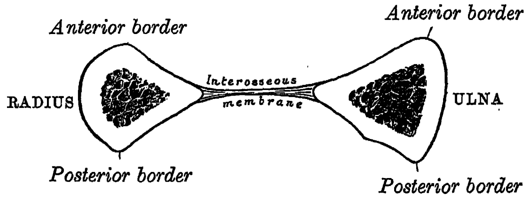


Fig. 415.—The upper part of the left ulna. Lateral aspect.

The **lower end** of the ulna is slightly expanded and comprises the rounded head and the styloid process. The *head* presents a convex articular surface on its lateral side for articulation with the ulnar notch of the radius. Its inferior surface (fig. 417) is smooth and is separated from the carpus by the articular disc of the inferior radio-ulnar joint, which is attached by its apex to the small rough area interposed between the articular surface and the styloid process. The *styloid process* is a short, rounded projection which springs from the posteromedial aspect of the lower end of the ulna. Its tip can be felt through the skin on the posteromedial aspect of the wrist, where it lies about 1 cm. above the level of the tip of the styloid process of the radius. On the dorsal surface of the lower end a shallow groove intervenes between the head of the ulna and the styloid process.

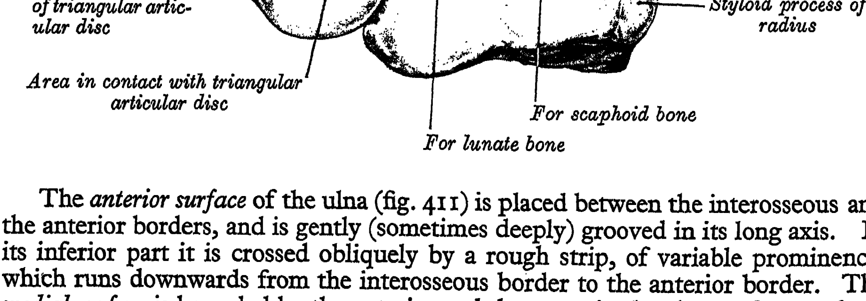
The **shaft** of the ulna is triangular in section (fig. 416) in its upper three-fourths, but is almost cylindrical in its lower fourth. The surfaces of the shaft are anterior, posterior and medial; the borders, interosseous, posterior and anterior.

FIG. 416.—A transverse section through the left radius and ulna, showing the attachment of the antebrachial interosseous membrane. Superior aspect.



The *interosseous border* is the lateral margin of the bone and forms a conspicuous crest in its middle two-fourths. The upper part becomes continuous with the posterior border of the depression which lies below the radial notch and is here termed the *supinator crest*; its lower part fades away on the cylindrical, lower portion of the shaft. The *anterior border* is thick and rounded. It commences above at the medial side of the tuberosity of the ulna and inclines backwards below where it can usually be traced to the base of the styloid process. The *posterior border*, also thick and rounded, commences at the apex of the posterior aspect of the olecranon and curves laterally as it descends. Inferiorly, it is very indistinct as it descends to the styloid process. Throughout its whole length this border can easily be felt through the skin.

FIG. 417.—The lower ends of the right radius and ulna.



The *anterior surface* of the ulna (fig. 411) is placed between the interosseous and the anterior borders, and is gently (sometimes deeply) grooved in its long axis. In its inferior part it is crossed obliquely by a rough strip, of variable prominence, which runs downwards from the interosseous border to the anterior border. The *medial surface* is bounded by the anterior and the posterior borders. Convex from side to side, it is smooth and featureless. The *posterior surface* (fig. 412) lies between the posterior and the interosseous borders. It is subdivided into three areas, of which the uppermost is limited by an oblique line—not always easily discernible—which runs upwards and medially from the junction of the middle and upper thirds of the posterior border to the posterior end of the radial notch. The region below this line is divided into a larger medial and a narrower lateral strip by a vertical ridge, usually distinct in its upper three-fourths but difficult to determine in its lower part.

Particular features.—The upper surface of the *olecranon* gives attachment, in front, to the capsular ligament of the elbow-joint; in its posterior two-thirds, which are roughened, it provides insertion for the tendon of the triceps muscle. Occasionally these two areas are separated by a smooth bursal area. The medial surface of the process is marked in its

upper part by a rough elevation, which gives attachment to the posterior and oblique bands of the medial ligament of the elbow-joint and the ulnar head of the flexor carpi ulnaris. Its lower part is smooth and gives origin to the uppermost fibres of the flexor digitorum profundus. The lateral surface of the process, and the adjoining part of the posterior surface of the shaft down to the oblique line already mentioned (p. 354), gives insertion to the anconeus muscle. Its posterior surface is separated from the skin by a bursa.

The anterior surface of the *coronoid process*, including the tuberosity of the ulna, receives the insertion of the brachialis muscle. Its medial border is sharp, and a small, rounded tubercle is situated at its upper end. This tubercle gives attachment to the oblique and anterior bands of the medial ligament of the elbow-joint and to the lowest part of the humero-ulnar head of the flexor digitorum sublimis muscle. Below the tubercle the margin gives origin to the coronoid head of the pronator teres, and below that to an occasional coronoid head of the flexor pollicis longus. The medial surface of the process is concave and gives origin to fibres of the flexor digitorum profundus. The anterior and posterior borders of the radial notch provide attachment for the annular ligament of the radius. The depressed area below the notch is limited behind by the *supinator crest*; the supinator muscle arises from the crest and from the adjoining part of the depression.

The part of the *trochlear notch* which is formed by the olecranon is, typically, divided into three areas. Of these the most medial faces forwards and slightly medially and is hollowed out to fit the medial flange of the trochlea: the intermediate area is flattened and fits the lateral flange of the trochlea; the most lateral area, which forms a narrow strip directed to the radial side, comes into contact with the trochlea only when the elbow is extended. The constriction of the articular surface is more pronounced than the constriction of the base of the olecranon. The resulting small non-articular parts of the anterior surface of the olecranon are covered in the fresh specimen and in life by tag-like processes of the synovial membrane which contain a little fat (fig. 533). The *coronoid part* of the trochlear notch is divided into medial and lateral parts, which correspond, respectively, to the medial and intermediate parts of the olecranon area. Of these the medial is hollowed out much more than the lateral, in conformity with the convexity of the medial flange of the trochlea. The medial and anterior borders of this area give attachment to the medial and anterior portions of the capsular ligament of the elbow-joint.

The carrying angle and its functional importance are described on p. 467.

The subcutaneous *posterior border* of the ulna gives attachment to the deep fascia of the forearm, which acts, in its upper three-fifths, as an additional origin for the flexor carpi ulnaris, and in its middle third as an additional origin for the extensor carpi ulnaris. Both of these muscles are therefore connected to the posterior border. The *interosseous border* is usually continuous above with the supinator crest. Except at its upper end it gives attachment to the interosseous membrane of the forearm. The rounded *anterior border* is covered in its upper three-fourths by the flexor digitorum profundus, to which it gives origin.

The *anterior surface* gives origin in its upper three-fourths to the flexor digitorum profundus. In the same extent the muscle arises also from the anterior border and the *medial surface*, extending upwards on to the medial sides of the coronoid process and the olecranon. The rough strip which crosses the lower fourth of this surface provides origin for the pronator quadratus. The anconeus is inserted into the *posterior surface* above the oblique line already mentioned, and extends upwards on to the lateral aspect of the olecranon. The narrow strip between the interosseous border and the vertical ridge gives part origin to three of the deep muscles of the forearm. The abductor pollicis longus arises from its upper fourth, and a ridge may separate this area from the succeeding fourth, which gives attachment to the extensor pollicis longus. The extensor indicis is attached to the third fourth of this area. The broad strip to the medial side of the vertical ridge is devoid of muscular attachments but is covered by the extensor carpi ulnaris, the tendon of which occupies the groove on the posterior aspect of the lower end of the bone. The medial ligament of the wrist-joint is attached to the tip of the *styloid process*. The articular disc separates the *head* of the ulna from the medial part of the lunate bone and, in ulnar deviation of the hand, from the triquetral bone.

Structure.—The structure of the ulna is similar to that of the other long bones.

Ossification (figs. 418, 419).—The ulna is ossified from three centres: one each for the shaft, the lower end, and the top of the olecranon. Ossification begins near the middle of the shaft, about the eighth week of intrauterine life, and soon extends through its greater part. About the fourth year, the centre for the lower end appears in the middle of the head, and extends into the styloid process. About the tenth year, a centre appears in the olecranon and forms a thin scale for the top of the process, the chief part of the process being formed by an upward extension of the shaft; sometimes the upper part of the olecranon

is ossified from two centres. The upper epiphysis joins the shaft about the sixteenth, the lower about the twentieth year. The former may take part in the formation of the semilunar notch although it does not usually do so.

Applied Anatomy.—When indirect force is applied to the forearm the radius as a rule gives way, though both bones may suffer. Fractures from indirect force generally take place somewhere about the middle of the bones, while those from direct violence may occur at any part, but are most frequent in the lower half of the bones. A point of interest

FIG. 418.—A plan of the ossification of the ulna. From three centres.

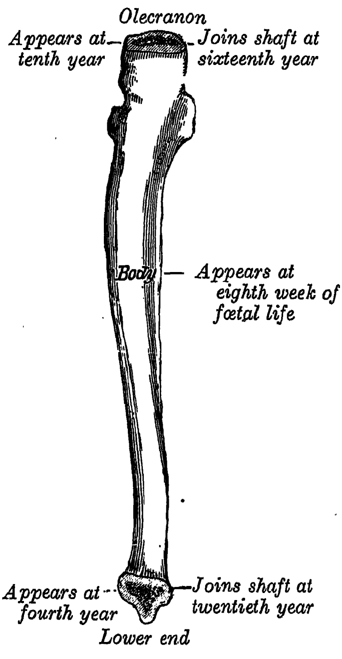
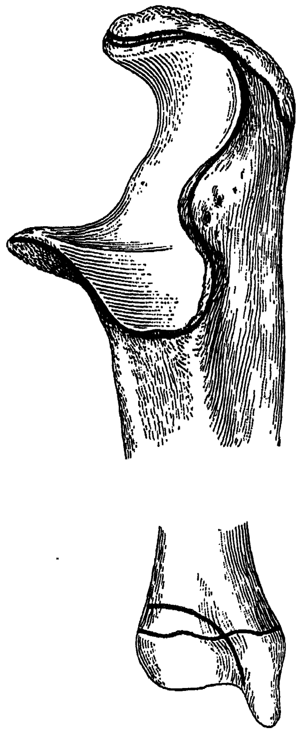


FIG. 419.—The epiphyseal lines of the left ulna in a young adult. Lateral aspect.



The lines of attachment of the articular capsules are in blue.

in connexion with these fractures is the tendency for the two bones to unite across the interosseous membrane; the limb should therefore be put up in a position midway between supination and pronation, which is not only the most comfortable position, but also separates the bones most widely from each other.

The special fractures of the ulna are: (1) Fracture of the olecranon: the most common fracture is at the constricted portion where the olecranon joins the shaft of the bone, and the fracture is usually transverse; but any part may be broken, and even a thin shell may be torn off. If the fibrous structures around the process are not torn, the displacement is slight, otherwise the olecranon may be drawn up for a very considerable distance. (2) Fracture of the coronoid process may occur as a complication of dislocation backwards of the bones of the forearm, but it is doubtful if it ever takes place as an uncomplicated injury. (3) Fractures of the shaft of the ulna may occur at any part, but usually take place at or a little below the middle of the bone. (4) The styloid process may be knocked off by direct violence.

Fractures of the radius may consist of: (1) Fracture of the head of the bone. (2) Fracture of the neck. (3) Fractures of the shaft of the radius are very common, and may take place at any part of the bone. In fracture of the upper one-third of the shaft—that is to say, above the insertion of the pronator teres—the displacement is very great. The upper fragment is strongly supinated by the biceps and the supinator, and flexed by the biceps; while the lower fragment is pronated and drawn towards the ulna by the two pronators. If such a fracture is put up in the ordinary position, midway between supination

and pronation, the bone will unite with the upper fragment in a position of supination, and the lower one in the mid-position, and thus considerable impairment of the movement of supination will result; the limb should therefore be put up with the forearm supinated. (4) The most important fracture of the radius is that of the lower end (Colles's fracture). The fracture is transverse, and generally takes place about 2·5 cm. from the lower end. Separation of the lower epiphysis of the radius may take place in the young. This injury and Colles's fracture may be distinguished from other injuries in this neighbourhood—especially dislocation of the wrist, with which they are liable to be confounded—by observing the relative positions of the styloid processes of the ulna and radius. In the natural conditions of parts, with the arm hanging by the side, the styloid process of the radius is on a lower level than that of the ulna. After fracture or separation of the epiphysis the styloid process of the radius is on the same level as, or on a higher level than, that of the ulna, whereas it would be unaltered in position in dislocation.

THE SKELETON OF THE HAND

The skeleton of the hand has three segments: (1) the carpal or wrist bones; (2) the metacarpal bones or bones of the palm; and (3) the phalanges or bones of the digits.

THE CARPUS (figs. 420–423)

General features.—The **carpus** is made up of eight short bones, which are arranged in a proximal and a distal row, each containing four bones. The carpal bones of the proximal row are named, from the lateral to the medial side, the *scaphoid* (*navicular*), *lunate*, *triquetral and pisiform*; those of the distal row, the *trapezium* (*os multangulum majus*), the *trapezoid* (*os multangulum minus*), the *capitate* and the *hamate*. Of these, the pisiform is placed on the anterior surface of the triquetral and is separated from the other carpal bones, all of which articulate with their immediate neighbours. The other bones of the proximal row form an arch convex upwards, which articulates with the radius and the articular disc of the inferior radio-ulnar joint. The concavity of the arch is directed downwards and forms a mortise for the upwardly projecting parts of the capitate and hamate bones. In this way the two rows are locked to each other and stability is assured.

The dorsal aspect of the whole carpus is gently convex from side to side, but the anterior surface is deeply concave, owing to the presence of certain forward projections on its lateral and medial borders. The *pisiform bone* lies at the medial part of the upper border of the muscular prominence (hypothenar eminence) which marks the medial portion of the palm, and its position on the front of the triquetral makes it easy to feel through the skin. In addition, the distal part of the *hamate bone* bears a *hook-like process* on its anterior surface. The concavity of the hook is directed towards the lateral side and its tip can be identified in the living subject. It lies 2·5 cm. distal to the pisiform and in line with the ulnar border of the ring finger. The projecting lateral border of the carpal groove is formed by the *tubercle of the scaphoid* and the *crest of the trapezium*. The tubercle is placed on the distal part of the anterior surface of the scaphoid and can be felt—and sometimes seen—as a small, rounded knob, at the medial part of the upper border of the muscular prominence (thenar eminence) which marks the lateral portion of the palm. The crest of the trapezium forms a rounded ridge which runs vertically across the anterior surface of the bone, being slightly hollowed out on its medial side. It lies immediately below and slightly lateral to the tubercle of the navicular, and can be felt only on deep pressure. The margins of the groove give attachment to a strong fibrous retinaculum, which retains the flexor tendons within an osteofibrous, carpal tunnel and so increases the efficiency of the flexor muscles. In addition, the retinaculum serves to increase the stability of the carpus. The anterior and posterior surfaces of the carpal bones—apart from the triquetral and the pisiform—are rough for the attachment of ligaments (radiocarpal, intercarpal and carpometacarpal).

Fig. 420.—The carpus and metacarpus of the left hand. Palmar aspect.

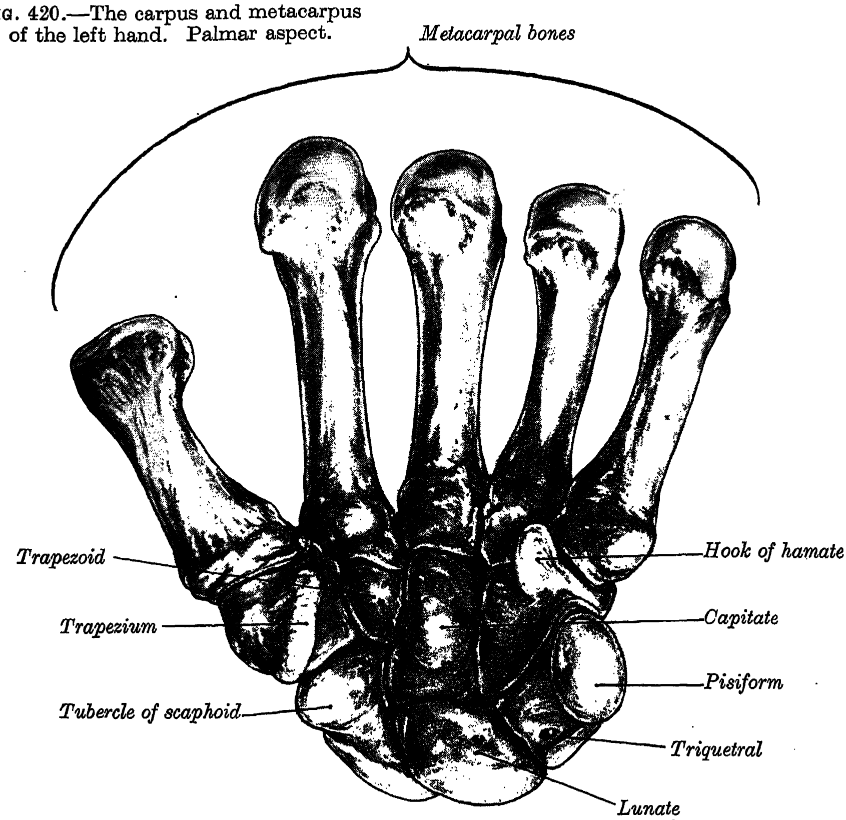
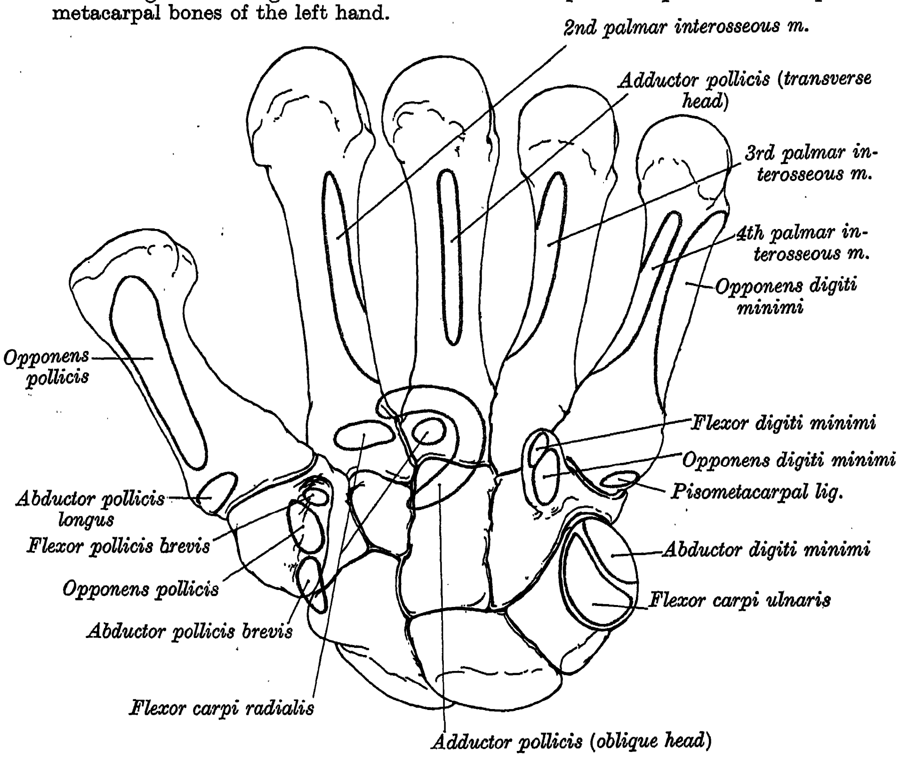


Fig. 421.—Diagram showing the muscles attached to the palmar aspects of the carpal and metacarpal bones of the left hand.



The dorsal interosseous muscles are not shown.

FIG. 422.—The carpus and metacarpus of the left hand. Dorsal aspect.

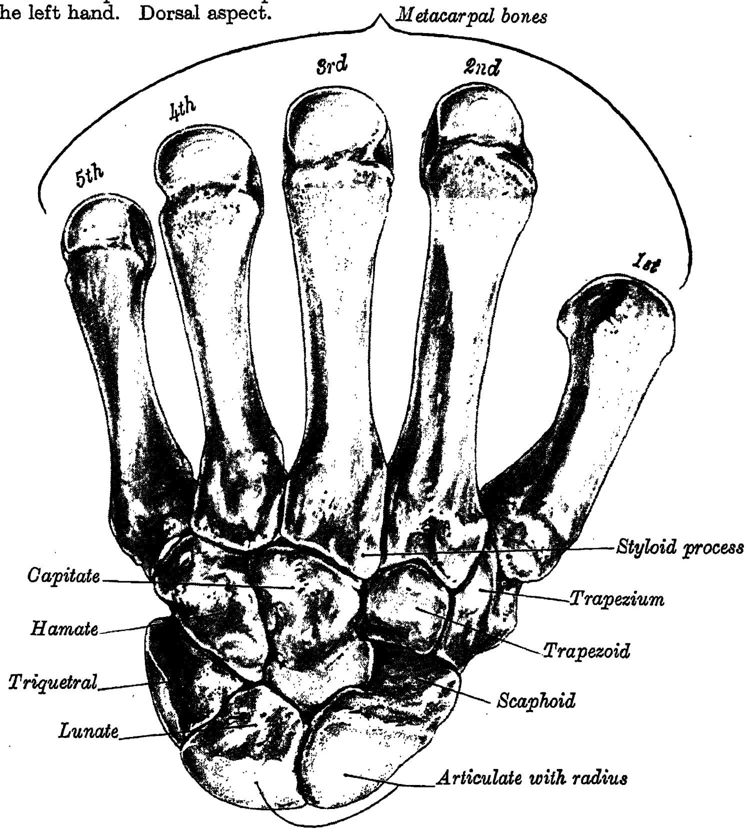
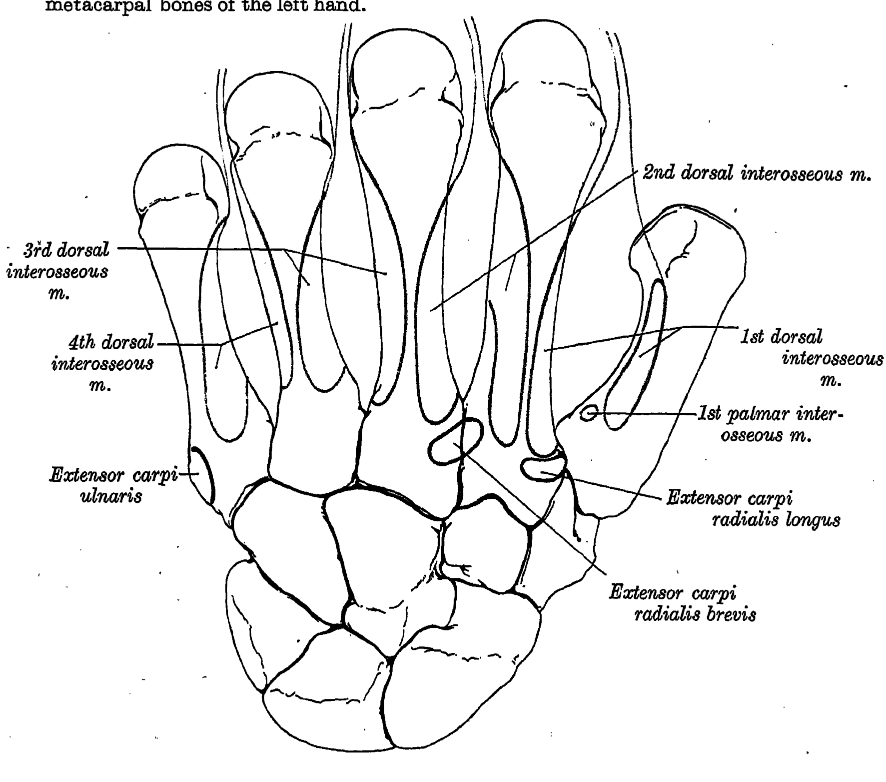


FIG. 423.—Diagram showing the muscles attached to the dorsal aspects of the carpal and metacarpal bones of the left hand.



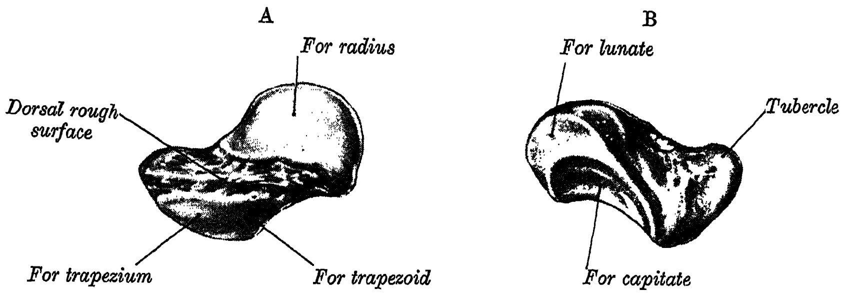
THE INDIVIDUAL CARPAL BONES

The Scaphoid Bone [Os Scaphoideum]

The **scaphoid** (B.N.A. **navicular**) **bone** (figs. 424, A and B) is named from its fancied resemblance to a boat. It is the largest bone in the proximal row and lies with its long axis directed downwards, laterally and slightly forwards. The tubercle forms a rounded elevation on the lower part of the *anterior surface* and is directed slightly to the lateral side. It gives attachment to the flexor retinaculum and a few fibres of the abductor pollicis brevis, and is crossed by the tendon of the flexor carpi radialis, which should be relaxed when the bony prominence is being examined. The *posterior surface* is rough and slightly grooved, and is narrower than the anterior surface. The *lateral surface*, also narrow and roughened, gives attachment to the lateral ligament of the wrist-joint. The remaining surfaces of the bone are articular. The *radial surface* is convex and is directed upwards and laterally. The *lunate surface* is a flattened, narrow semilune, directed medially. The *capitate surface*, large and concave, is directed medially and downwards. The *surface for the trapezium and the trapezoid bones* forms a continuous convex area, directed downwards.

Fig. 424.—The left scaphoid bone.

Viewed (A) from behind, and (B) from in front.

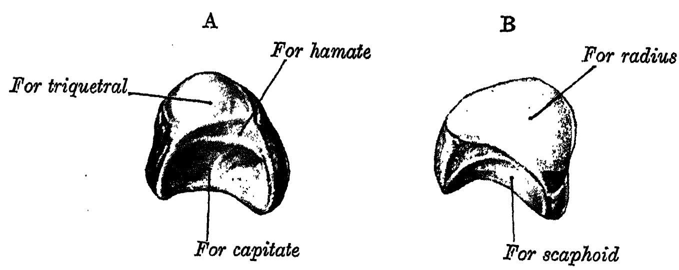


The Lunate Bone [Os Lunatum]

The **lunate bone** (figs. 425, A and B), distinguished by its crescentic outline, is placed between the scaphoid and the triquetral bones in the middle of the proximal row of the carpus. The rough, *anterior surface*, almost triangular in outline, is larger and wider than the rough, *posterior surface*. The smooth, convex, *proximal surface* articulates with the radius and the articular disc of the inferior radio-ulnar joint. The *lateral surface* is narrow and presents a flat, semilunar facet for articulation with the scaphoid. The *medial surface* articulates with the triquetral and is almost square. It is separated from the distal surface by a curved ridge, which is usually somewhat hollowed out (fig. 425, A) for articulation with the edge of the wedge-shaped hamate bone (fig. 420). The *distal surface* is deeply concave to accommodate the medial part of the head of the capitate bone

Fig. 425.—The left lunate bone.

A. Inferomedial aspect. B. Superolateral aspect.



The Triquetral Bone [Os Triquetrum]

The **triquetral bone** (fig. 426), usually pyramidal in shape, is distinguished by an oval, isolated, smooth facet for articulation with the pisiform, which marks the distal part of its rough, *anterior* surface. The *medial* and *dorsal surfaces* are confluent. Rough distally for the attachment of the medial ligament of the wrist-joint, this aspect is smooth in its proximal part, which articulates with the articular disc of the inferior radio-ulnar joint in full adduction of the hand. The *hamate surface*, directed laterally and downwards, forms a concavo-convex area, broad proximally and narrow distally. The *lunate surface*, almost square, is directed upwards and laterally.

Fig. 426.—The left triquetral bone. Palmar aspect.

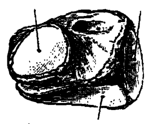
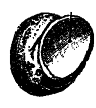


Fig. 427.—The left pisiform bone. Dorsal aspect.



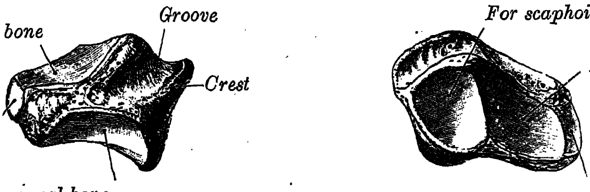
The Pisiform Bone [Os Pisiforme]

The **pisiform bone** (fig. 427), shaped like a pea with one flattened surface, can be distinguished by the fact that it possesses only one articular facet. This is on the *posterior surface* of the bone to articulate with the triquetral, and its long axis runs downwards and laterally. The non-articular part of the bone tends to project downwards beyond the articular surface, and the lateral aspect is somewhat flattened, while the medial aspect is convex. The flexor carpi ulnaris is inserted on the anterior surface and its true continuation, viz., the pisometacarpal ligament, to the distal part of the bone. The flexor retinaculum (transverse carpal ligament) is attached to the anterior part of the lateral aspect, while the abductor digiti minimi and the extensor retinaculum (dorsal carpal ligament) are attached to the medial aspect. The area surrounding the articular facet is slightly constricted and gives attachment to the capsular ligament of the pisotriquetral joint.

The Trapezium Bone [Os Trapezium]

The **trapezium (greater multangular) bone** (fig. 428) can be identified by the crest and groove which mark its rough, *anterior surface*. The groove, which is medial to the crest, lodges the tendon of the flexor carpi radialis, and its margins give attachment to the two layers of the flexor retinaculum (fig. 629 and p. 609). The *crest* is obscured to a large extent by the origin of the muscles of the thenar eminence. The opponens pollicis

Fig. 428.—The left trapezium bone. Palmar and superomedial aspects.



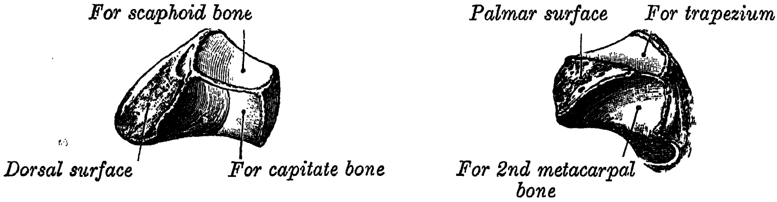
arises from its middle part, the flexor pollicis brevis from its distal part and the abductor pollicis brevis from its proximal part (fig. 421). The elongated, rough, *dorsal surface* is closely related to the radial artery, before it passes forwards into the palm to become the deep palmar (volar) arch. The *lateral surface* also is large and rough for the attachment of the lateral ligament of the wrist-joint and the capsular ligament of the carpometacarpal joint of the thumb. A large *saddle-shaped surface* is directed downwards and laterally for articulation with the base of the metacarpal bone of the thumb. The most distal part of the bone projects slightly between the bases of the first and second metacarpal bones and is covered with a small, quadrilateral facet which is directed downwards and medially to articulate with a corresponding facet on the posterior part of the lateral aspect of the base of the second

metacarpal bone. The medial surface is covered with a large, gently concave facet for articulation with the trapezoid bone. The proximal surface is occupied by a small, slightly hollowed out facet, which articulates with the scaphoid bone.

The Trapezoid Bone [Os Trapezoideum]

The **trapezoid** (lesser **multangular**) **bone** (fig. 429) is small and very irregular in shape. The *anterior surface* is rough, narrow and considerably smaller than the rough, *dorsal surface*. It is continued for a short distance on to the inferolateral aspect. The *distal surface* artic-

FIG. 429.—The left trapezoid bone. Superomedial and inferolateral aspects.

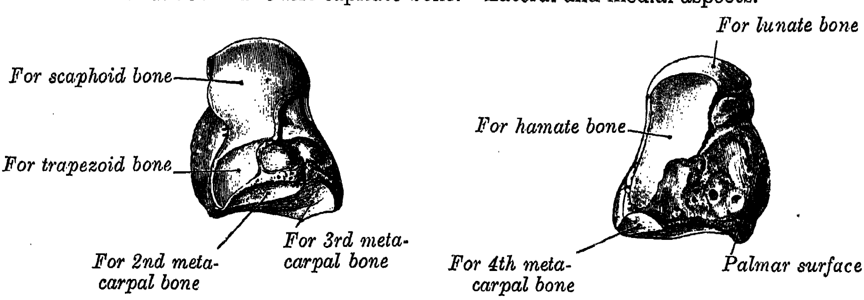


ulates with the grooved base of the second metacarpal bone. Triangular in outline, it is convex from side to side and concave from before backwards. The *medial surface* articulates with the distal part of the capitate bone, by means of a slightly concave facet. The dorsal part of this area is often rough for the attachment of an interosseous ligament. The *lateral surface* articulates with the trapezium, and the *distal surface* with the scaphoid bone.

The Capitate Bone [Os Capitatum]

The **capitate bone** (fig. 430) is the largest of the carpal bones and is placed opposite the base of the third metacarpal bone ; it is therefore more or less central in position. The *distal surface* is roughly triangular and forms a concavoconvex facet for articulation with the base of the third metacarpal bone. Its lateral border is marked by a concave strip which

FIG. 430.—The left capitate bone. Lateral and medial aspects.



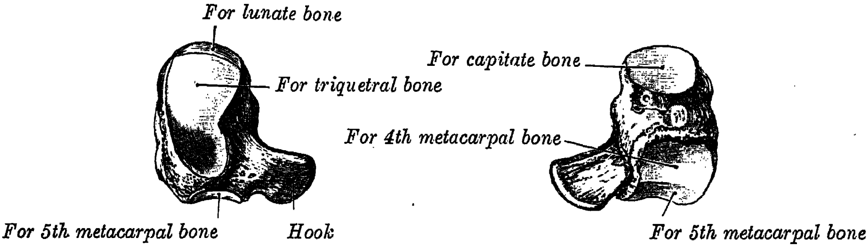
articulates with the medial side of the base of the second metacarpal bone, and its posteromedial angle usually bears a small facet for the fourth metacarpal bone. The convex *head* is received into the concavity formed by the lunate and scaphoid bones. Its *proximal surface* articulates with the lunate and its *lateral surface* with the scaphoid. The facet for the scaphoid is usually continuous with the facet for the trapezoid on the lower part of the lateral surface of the bone, but the two may be separated by a rough interval. The *medial surface* presents a large facet for the hamate bone, deeper above than below, where a part of the surface is non-articular and gives attachment to a strong interosseous ligament. The anterior and posterior surfaces are roughened ; the posterior is the larger of the two.

The Hamate Bone [Os Hamatum]

The **hamate bone** (fig. 431) can be identified easily by its wedge-shaped form and the hook-like process which projects from the distal part of its rough, *anterior surface.* The concavity of the *hook* is directed to the lateral side, and takes part in the formation of the carpal tunnel. Its tip gives attachment to the flexor retinaculum (transverse carpal

ligament), and more medially to the flexor and the opponens digiti minimi. The distal aspect of the base of the hook occasionally shows a slight transverse groove for the deep terminal branch of the ulnar nerve. The rest of the *anterior surface*, like the *posterior surface*, is rough for the attachment of ligaments. The *distal surface* is divided into two articular surfaces by a faint ridge: of these, the smaller, lateral facet articulates with the base of

FIG. 431.—The left hamate bone. Medial and inferolateral aspects.



the fourth, and the larger, medial facet with the base of the fifth metacarpal bone. The *proximal surface* is the cutting edge of the wedge and usually bears a narrow facet for the lunate bone. The *medial surface* is covered by a broad articular strip, convex above and concave below, for the triquetral bone. The *lateral surface* articulates with the capitate bone by means of a facet which covers all but the antero-inferior part of the surface.

THE METACARPUS

General features.—The **metacarpus** (figs. 420-423) comprises five metacarpal bones, which are numbered from the lateral to the medial side. They are miniature long bones, and each possesses a rounded head, a shaft and an expanded base. The *head* is at the distal end of the bone and articulates with the proximal phalanx. Its oblong, articular surface is convex, the degree of convexity being less in the transverse than in the anteroposterior direction, and extends farther upwards on the palmar surface than on the dorsal surface. The prominence of the knuckles is produced by the heads of the metacarpal bones. The *bases* of the metacarpal bones are formed by their expanded proximal ends, which articulate with the distal row of the carpus and with one another—save that the first metacarpal bone is isolated from the rest and does *not* articulate with the metacarpal bone of the index. The *shafts* are concave longitudinally on their palmar surfaces, an arrangement which provides a hollow for the lodgment of the muscles of the palm. The dorsal surface of each presents a flattened triangular area in its distal part, continued proximally as a rounded ridge. These flattened areas can be felt on the back of the hand in the living subject immediately proximal to the knuckles.

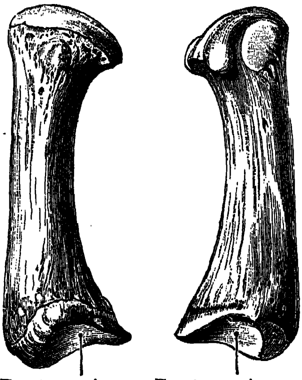
It should be observed that, whereas the medial four metacarpal bones lie side by side, the first metacarpal bone lies on a more anterior plane and that it is rotated medially round its long axis through an angle of 90°. As a result of this rotation its morphologically dorsal surface is directed to the lateral side, its radial border forwards, its palmar surface medially, and its ulnar border backwards. By virtue of its anterior position the thumb moves medially in front of the palm when it is flexed and it can be opposed to each of the fingers in turn. The ability to oppose the thumb to the fingers is rendered possible by the rotation of the bone medially. It is the most important factor in rendering the hand an efficient instrument for prehension, for, when an object is grasped in the hand, the fingers encircle it from one side and the thumb from the other, and the power of the grip is increased very greatly thereby.

THE CHARACTERS OF THE INDIVIDUAL METACARPAL BONES

The first metacarpal bone (fig. 432) is shorter and stouter than any of the others. Its dorsal surface is directed laterally, a fact which can easily be confirmed in the living hand, and its long axis passes downwards and laterally, diverging from its neighbour. The *shaft* is flattened and its dorsal surface is uniformly broad and convex from side to side. The palmar surface is concave from above downwards and is subdivided by a rounded ridge into a larger anterolateral and a smaller anteromedial surface. The opponens pollicis is inserted

into the radial border and the adjoining part of the anterolateral surface; the radial head of the first dorsal interosseous muscle arises from the ulnar border and the adjoining part of the anteromedial surface. The *base* presents a concavoconvex surface for articulation with the trapezium (greater multangular bone). On its lateral side it receives the insertion of the abductor pollicis longus; its ulnar side gives origin to the first palmar interosseous muscle (deep head of the flexor pollicis brevis). The *head* is less convex than the heads of the other metacarpal bones, and is broader from side to side than from before backwards. On its palmar surface the ulnar and radial corners are enlarged to form two articular eminences, on each of which a sesamoid bone glides.

Fig. 432.—The first left metacarpal bone. Lateral and medial aspects.



The **second metacarpal bone** (fig. 433) is the longest of all the metacarpal bones, and its base is the largest. It can be identified by its grooved *base*. This groove (fig. 629) is concave from side to side and convex anteroposteriorly: it articulates with the trapezoid (lesser multangular) bone. It is bounded on its medial side by a deep ridge, the edge of which articulates with the capitate bone. The lateral side of the base is marked, nearer the dorsal than the palmar surface, by a small, quadrangular facet for the trapezium (os multangulum majus). Immediately behind this facet, i.e. on the lateral part of the dorsal surface of the base, a small rough impression gives insertion to the extensor carpi radialis longus. The palmar surface provides a small tubercle or ridge for the insertion of the flexor carpi radialis. The medial side of the base articulates with the lateral side of the base of the third metacarpal bone by a strip-like facet which is constricted at its middle.

The *shaft* is prismoid in form and curved so as to be convex backwards in its long axis and concave forwards. It has medial, lateral and dorsal surfaces. The dorsal surface is broad near the head but narrows into a ridge as it approaches the base. This surface is covered by the extensor tendons of the index finger, and its converging borders commence

Fig. 433.—The second left metacarpal bone. Dorsilateral and medial aspects.

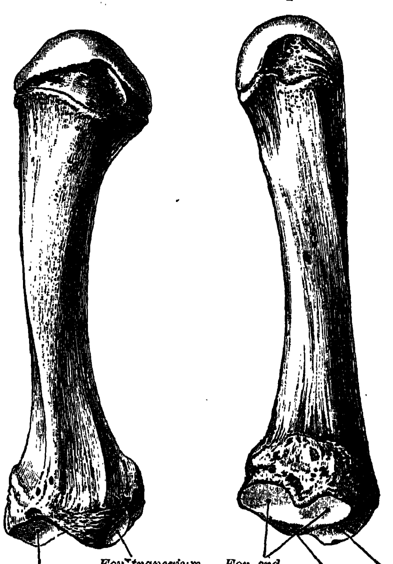
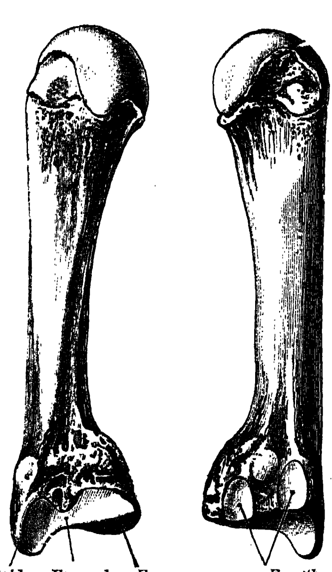


Fig. 434.—The third left metacarpal bone. Lateral and medial aspects.



in two little tubercles, which are situated one on each side of its head. The *lateral surface* inclines dorsally at its proximal end: it gives origin to the ulnar head of the first dorsal interosseous muscle. The *medial surface* also inclines dorsally at its proximal end and is divided into two nearly parallel strips by a faint ridge. Of these, the anterior gives origin to the second palmar interosseous and the posterior to the radial head of the second dorsal interosseous muscle.

The tubercles at the side of the head provide attachment for the collateral ligaments of the metacarpophalangeal joint.

The **third metacarpal bone** (fig. 434) can be identified by means of the short *styloid process* which projects upwards from the radial side of the dorsal surface of its base. The *base* articulates, proximally, with the capitate bone by means of a facet which is convex in front but concave behind, where it covers the anteromedial aspect of the styloid process. The lateral aspect of the base is marked by a strip-like facet, constricted at its middle, for articulation with the metacarpal bone of the index. On its medial side it articulates with the base of the fourth metacarpal bone by means of two small, discrete oval facets. Sometimes the anterior facet is absent, and less frequently the two may be connected by a narrow bridge along the medial border of the base. The palmar surface of the base receives a slip from the flexor carpi radialis tendon, while its dorsal surface, immediately beyond the styloid process, gives insertion to the extensor carpi radialis brevis.

The *shaft* resembles the shaft of the metacarpal bone of the index. Its lateral surface gives origin to the ulnar head of the second dorsal interosseous and its medial surface to the radial head of the third dorsal interosseous muscle. The palmar ridge which separates these two surfaces gives origin, in its distal two-thirds, to the transverse head of the adductor pollicis. Its dorsal surface is covered by the extensor tendon of the middle finger.

Fig. 435.—The fourth left metacarpal bone. Lateral and medial aspects.

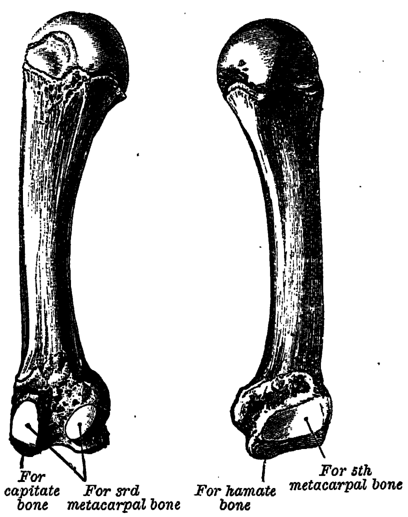
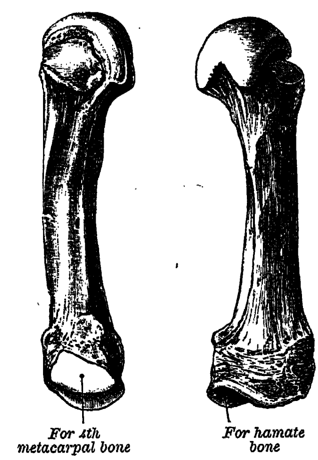


Fig. 436.—The fifth left metacarpal bone. Lateral and medial aspects.



The **fourth metacarpal bone** (fig. 435) is shorter and more slender than the metacarpal bones of the index and middle fingers. It can be identified by examination of the sides of its *base*. The lateral aspect bears two small, oval, discrete facets for articulation with the third metacarpal bone. Of these the posterior is usually (but not always) the larger, and its proximal part comes into contact with the capitate bone. The medial aspect is marked by a single elongated facet for the fifth metacarpal bone. The proximal surface articulates with the hamate bone by a quadrangular facet which is convex in front and concave behind.

The *shaft* resembles the shaft of the metacarpal bone of the index finger, but its lateral surface is traversed by a faint ridge, which separates the origin of the third palmar interosseous in front, from the origin of the ulnar head of the third dorsal interosseous muscle, behind. The medial surface gives origin to the radial head of the fourth dorsal interosseous muscle.

The **fifth metacarpal bone** (fig. 436) can be identified by the fact that the medial surface of the *base* is non-articular and presents a tubercle for the insertion of the extensor carpi ulnaris. The proximal surface of the base is covered by a facet, concave from side to side and convex from before backwards, for articulation with the hamate bone. Its lateral aspect presents an elongated strip-like facet for the fourth metacarpal bone.

The *shaft* is characterised by the fact that the triangular area on its dorsal surface reaches almost to the base and that only the lateral surface inclines dorsally at its proximal end. The medial surface gives insertion to the opponens digiti minimi; the lateral surface is divided by a longitudinal ridge, sometimes quite sharp and distinct, into an anterior strip for the origin of the fourth palmar interosseous, and a posterior strip for the origin of the ulnar head of the fourth dorsal interosseous muscle.

THE PHALANGES OF THE HAND

General features.—The **phalanges** are fourteen in number, three for each finger and two for the thumb. Each has a head, a shaft and a base or proximal end. In each the *shaft* tapers to its distal end and its dorsal surface is convex. The palmar surface is flattened from side to side, but is gently concave forwards in its long axis. The *bases* of the proximal phalanges are marked by concave, oval facets for articulation with the heads of the metacarpal bones. Their *heads* are pulley-shaped and ascend farther on the palmar than on the dorsal surfaces. To conform to the shape of the head of the proximal phalanx, the base of a middle phalanx is marked by two small, concave facets separated by a smooth ridge. The head of the middle phalanx also is pulley-shaped and the base of the distal phalanx conforms to it. The head of the distal phalanx is non-articular, but is marked on its palmar surface by a rough, horseshoe-shaped *tuberosity*, which serves to support the pulp of the finger-tip.

Particular features.—In addition to providing attachment for the ligaments of the joints in which they participate, the phalanges give insertion to numerous muscles. The base of the distal phalanx gives attachment on its palmar surface to the corresponding tendon of the *flexor digitorum profundus* and on its dorsal surface to the *extensor digitorum*. The sides of the middle phalanx receive the insertion of the *flexor digitorum sublimis* tendon (p. 600) and the *fibrous flexor sheath*. Its base gives attachment on its dorsal surface to a part of the *extensor digitorum* tendon. The sides of the proximal phalanx give attachment to the *fibrous flexor sheath*. Its base receives, on its lateral side, part of the insertion of the corresponding *lumbrical muscle* and an *interosseous muscle*, and on its medial side another *interosseous muscle*.

The phalanges of the *little finger* and the *thumb* differ in certain respects from the other three. The medial side of the base of the proximal phalanx of the little finger receives the insertion of the *abductor digiti minimi* and the *flexor digiti minimi*. The base of the proximal phalanx of the thumb receives on its dorsal surface the tendon of the *extensor pollicis brevis*; on its lateral surface the *abductor pollicis brevis*, the *flexor pollicis brevis* and the lateral part of the *oblique head* of the *adductor pollicis*; and, on its medial surface, the *transverse* and the remainder of the *oblique head* of the *adductor pollicis* and the *first palmar interosseous muscle* (deep head of the *flexor pollicis brevis*). The margins of the proximal phalanx of the thumb are not sharp like those of the other digits, as the fibrous flexor sheath is not so strongly developed in the case of the thumb.

THE OSSIFICATION OF THE BONES OF THE HAND

The centre for the capitate bone, which may be present at birth in the female, is the first to appear and that for the pisiform bone is the last, but the order in which the other carpal bones ossify is subject to considerable variation. *In the male*, the capitate and the hamate ossify during the first year; the triquetral bone, during the third year; the lunate, trapezium and scaphoid bones, during the fifth and sixth years; the trapezoid bone, during the eighth year; and the pisiform bone, about the twelfth year.

Occasionally an additional bone, named the *os centrale*, is found between the scaphoid, trapezoid and capitate bones. During the second month of intra-uterine life it is represented by a small cartilaginous nodule which usually fuses with the cartilaginous scaphoid. Sometimes the styloid process of the third metacarpal bone is detached and forms an additional ossicle.

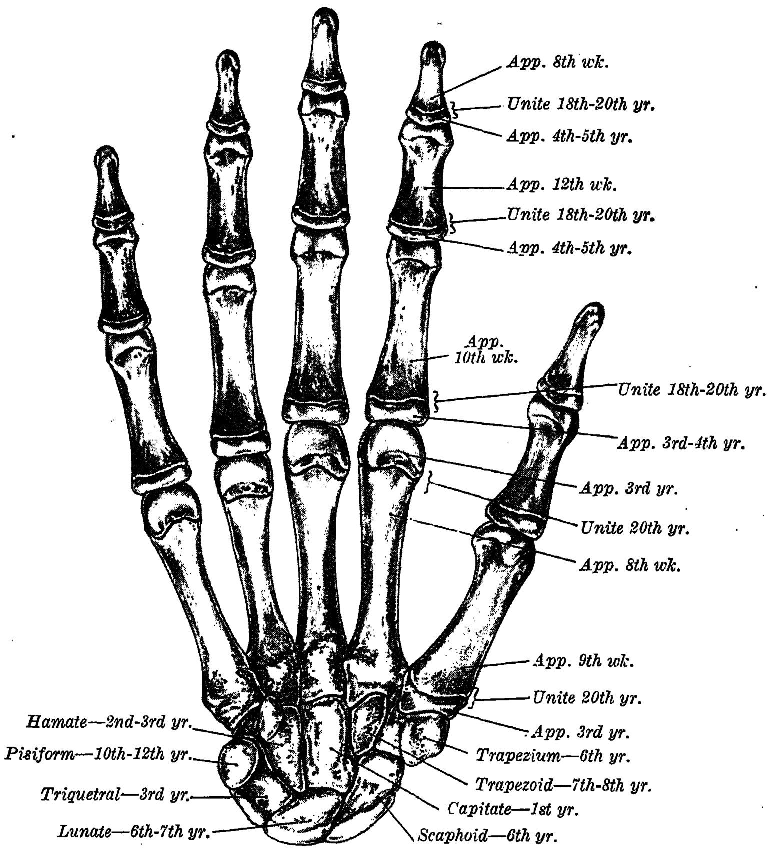
The **metacarpal bones** are each ossified from two centres: a primary centre for the shaft, and a secondary or epiphyseal centre for the base or proximal end of the first and for the head or distal end of each of the other four. The metacarpal bone of the thumb is ossified like a phalanx, and therefore some anatomists look upon the skeleton of the thumb as consisting of three phalanges, and not of a metacarpal bone and two phalanges; others believe that the distal phalanx represents fused middle and distal phalanges, a condition which has occasionally been observed in the little toe.* Ossification begins in the middle of the shaft about the eighth or ninth week of intrauterine life, the centres for the second and third metacarpal bones being the first to appear, and that for the first metacarpal bone the last. About the third year the base of the first

* See note on opposite page.

metacarpal bone, and the heads of the other metacarpal bones, begin to ossify; they unite with the shafts about the twentieth year.

It has been suggested (Parsons) that the presence of an epiphysis only at the distal end of a typical metacarpal may be associated with the greater range of movement which the metacarpophalangeal joint enjoys. In the thumb, on the other hand, it is the carpometacarpal joint which possesses the wider range of movement, and the presence of a basal epiphysis in the first metacarpal bone may be attributable to this fact.* Occasionally a distal epiphysis also is present in the first, and a basal or proximal epiphysis sometimes occurs in the second metacarpal.

FIG. 437.—The bones of the hand of a child, indicating the general plan of ossification.



The **phalanges** are each ossified from two centres; a primary centre for the shaft, and a secondary or epiphyseal centre for the proximal extremity. Ossification begins in the shaft about the eighth week of intrauterine life. The epiphyses for the bases of the proximal row of phalanges appear between the third and fourth years, and those for the middle and distal rows of phalanges a year later. All unite with the shafts between the eighteenth and twentieth years.

In the distal phalanges the centres for the shafts appear at the distal ends instead of at the middle of the shafts, as in the other phalanges. Moreover, of

* Broom (*Origin of the Human Skeleton*, Witherby, London, 1930) has put forward an ingenious explanation for the peculiar mode of ossification of the metacarpal bone of the thumb. His theory has recently been subjected to serious criticism by Nicholson ("Studies on Tumour Formation," *Guy's Hospital Reports*, vol. 87, No. 1, 1937), who has brought forward evidence to show that, when the thumb possesses an additional phalanx, the condition is always associated with the presence of a distal as well as a proximal epiphysis for its metacarpal bone. The metacarpal bone of the thumb sometimes bifurcates at its distal end. In these cases the medial branch, which has a distal epiphysis, bears a digit with three phalanges, while the lateral branch, which has no distal epiphysis, bears a digit with two phalanges.

all the bones of the hand, the distal phalanges are the first to ossify, and the middle phalanges the last.

Applied Anatomy.—The use of X-rays has shown that the carpal bones are more frequently fractured than was formerly supposed. When a single bone is broken it is usually the scaphoid or the capitate (more frequently the scaphoid) and the fracture runs at right angles to the long axis of the bone.

THE BONES OF THE LOWER LIMB

THE HIP-BONE (OS COXÆ)

General features.—The **hip-bone** (figs. 438-441) is a large, irregularly shaped bone, constricted in the middle and expanded above and below. Its *lateral surface* is marked near its middle by a deep, cup-shaped hollow, termed the **acetabulum,** which forms a secure socket for the rounded head of the femur. *Below* and *in front of* the acetabulum the bone presents a large, oval, or triangular, gap, termed the **obturator foramen.** *Above* the acetabulum the bone forms a wide, flattened plate, with a long, curved upper border termed the **iliac crest.** With this information the student should have no difficulty in assigning a given hip-bone to its appropriate side of the body.

The hip-bone articulates in front with the corresponding bone of the opposite side and the two bones form the pelvic girdle or girdles of the lower limbs (p. 331). Each consists of three parts, named the ilium, the ischium and the pubis, which are connected by cartilage in the young subject but are united by bone in the adult; the union of the three parts takes place in the walls of the acetabulum. The lines of fusion are shown as stippled bands in figs. 439 and 441. The *ilium* includes the upper part of the acetabulum and the expanded, flattened area of bone above it; the *ischium* includes the lower part of the acetabulum and the bone below and behind; the *pubis* forms the anterior part of the acetabulum and separates the ilium from the ischium in this situation; in addition, it forms the anterior part of the lower portion of the hip-bone and meets the pubis of the opposite side in the median plane.

The ilium.—General features. The ilium, so named because it supports the flank, possesses two ends and three surfaces. The lower end is the smaller and forms rather less than the upper two-fifths of the articular surface of the acetabulum; the upper end is greatly expanded and compressed to form the *iliac crest.* The surfaces are named the gluteal surface, the sacropelvic surface and the iliac fossa. The *gluteal surface* is directed backwards and laterally and forms an extensive rough area; the *iliac fossa* is smooth and gently hollowed out and occupies the anterior and upper part of the medial aspect of the ilium; the *sacropelvic surface* also is placed on the medial aspect and lies behind and below the iliac fossa, separated from it by a ridge termed the *medial border.*

The *iliac crest* is situated at the upper end of the ilium. It is convex upwards in its general outline, but is sinuously curved, being concave inwards in front and concave outwards behind. Its anterior and posterior extremities project a little beyond the bone below and are termed respectively the anterior and the posterior superior iliac spines. The *anterior superior spine* lies at the lateral end of the fold of the groin and can be felt without difficulty in the living subject; the *posterior superior spine* cannot be felt but it can be identified readily, because its position is indicated by a small dimple, which lies about 4 cm. lateral to the second spinous tubercle of the sacrum above the medial part of the buttock. Morphologically the crest consists of a long ventral and a shorter dorsal segment. The ventral segment forms rather more than the anterior two-thirds of the crest and is associated with alterations in the form of the ilium which were necessitated by the adoption of the erect attitude; the dorsal segment forms rather less than the posterior third of the crest and can be identified in all animals. The ventral segment of the crest is bounded by an *outer* and an *inner lip*, enclosing a rough *intermediate area*, which is narrowest at its middle and becomes wider both in front and behind. The *tubercle of the crest* (fig. 438) forms a prominent projection on the outer lip about 5 cm. or more behind and above the anterior superior spine. The dorsal segment presents two

sloping surfaces separated by a well-marked ridge, which terminates in the posterior superior spine. The highest point of the crest, which is a little behind its midpoint, is on the same level as the upper border of the body of the fourth lumbar vertebra.

The *lower end* of the ilium will be described with the acetabulum (p. 377).

The *anterior border* of the ilium descends to the acetabulum from the anterior superior spine. Its upper part is rounded and concave forwards; its lower part presents a roughened projection, termed the *anterior inferior iliac spine*, which lies immediately above the acetabulum.

The *posterior border* is irregularly curved (fig. 438). It commences at the posterior superior spine and runs at first downwards and forwards, with a backward concavity, forming a small notch. At the lower end of the notch the bone presents a wide, low projection, termed the *posterior inferior spine*, where the posterior border makes a sharp bend. It then runs almost horizontally forwards for about 3 cm. and finally turns downwards and backwards to become continuous with the posterior border of the ischium. As a result the posterior border shows a deep notch, termed the *greater sciatic notch*, which is bounded above by the ilium and below by the ilium and ischium.

The *medial border* is placed on the medial surface of the bone and separates the iliac fossa from the sacropelvic surface. Indistinct near the crest, it is roughened in its upper part, then sharp and clear-cut where it bounds the articular surface for the sacrum, and finally smooth and rounded. The last-named portion forms the *iliac part of the arcuate line*—the line marks the inlet of the true pelvis; at its inferior end it reaches the posterior part of the *iliopubic* (*iliopectineal*) *eminence*, which is placed at the union of the ilium with the pubis.

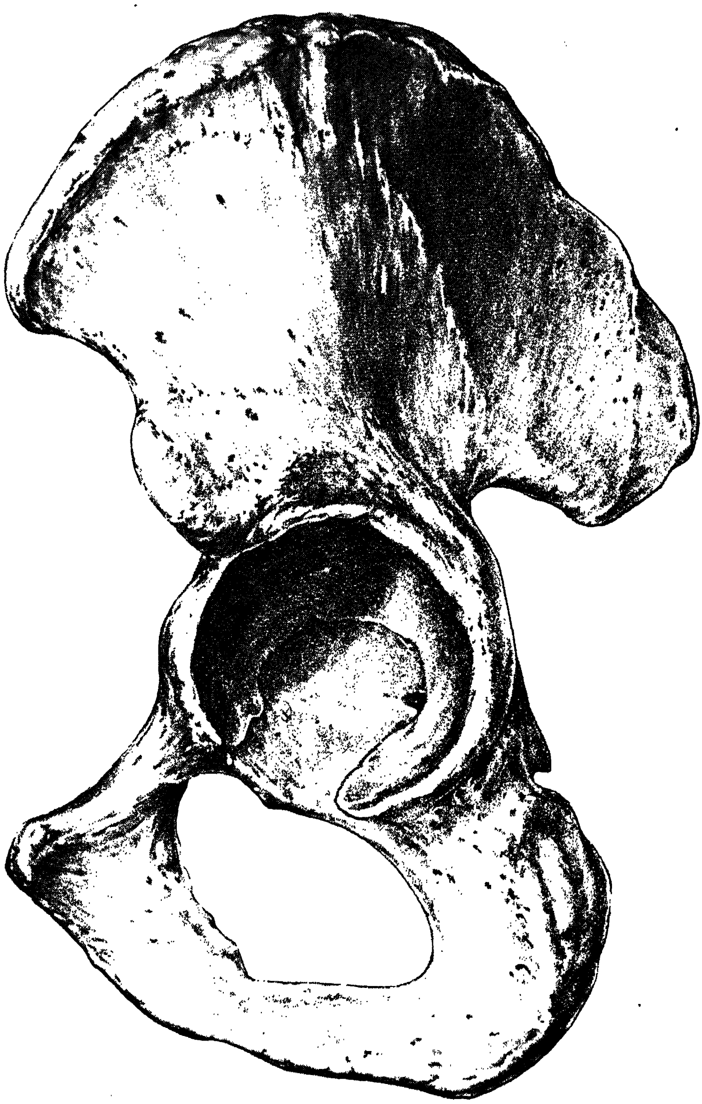
The *gluteal surface* (fig. 438) is directed backwards and laterally in its posterior part, and laterally and slightly downwards in front. It is bounded above by the iliac crest, below by the upper border of the acetabulum and in front and behind by the anterior and posterior borders. The surface, as a whole, is smooth and curved, being convex in front and concave behind, but it is marked by three roughened ridges termed the posterior, middle and inferior gluteal lines. The *posterior gluteal line*, which is the shortest of the three, begins above on the outer lip of the crest about 5 cm. in front of its posterior extremity and ends below a short distance in front of the posterior inferior spine. Its upper part is usually distinct, but its lower part is ill-defined and frequently absent. The *middle gluteal line* (anterior gluteal line), which is the longest of the three, begins about the middle of the upper margin of the greater sciatic notch and runs upwards and forwards to become confluent with the outer lip of the crest a little in front of the tubercle. The *inferior gluteal line*, which is rarely a prominent feature, begins a little above and behind the anterior inferior spine and curves backwards and downwards to end near the apex of the greater sciatic notch. Between the inferior gluteal line and the margin of the acetabulum there is a rough, shallow groove on the bone. Behind the acetabulum the lower part of the gluteal surface becomes continuous with the posterior surface of the ischium. The site of union of these two elements is marked by a low elevation.

The *iliac fossa* occupies the anterior and upper part of the medial aspect of the ilium. It is limited above by the iliac crest; in front by the anterior border, and behind by the medial border, by which it is separated from the sacropelvic surface. The surface is smooth and gently concave and forms the posterolateral wall of the false pelvis. Below it is continuous with a shallow groove (fig. 440) bounded laterally by the anterior inferior spine and medially by the iliopubic (iliopectineal) eminence.

The *sacropelvic surface* (fig. 440) occupies the posterior and lower part of the medial aspect of the ilium. It is bounded behind and below by the posterior border, in front and above by the medial border, and above and behind by the iliac crest. It is subdivided into three areas, viz., the iliac tuberosity, the auricular surface and the pelvic surface. The *iliac tuberosity* is an extensive, roughened, tuberculated and pitted area which lies immediately below the dorsal segment of the iliac crest. It gives attachment to the strong ligaments on the dorsal surface of the sacro-iliac joint. The *auricular surface* (fig. 440) is placed immediately below and in front of the tuberosity, and articulates with the lateral mass of the sacrum. It is shaped like the auricle—the wide expanded portion lying above and in front, and the

lobule below and behind, covering the medial aspect of the posterior inferior spine. The edges are sharp and clearly defined, but the surface, although articular, is finely roughened and irregular. The *pelvic surface* lies below and in front of the auricular surface and helps to form the wall of the true pelvis. It comprises an upper and a lower portion. The upper portion faces downwards and lies between the margin of the auricular surface and the upper border of the greater sciatic notch.

FIG. 438.—The left hip-bone. External surface.

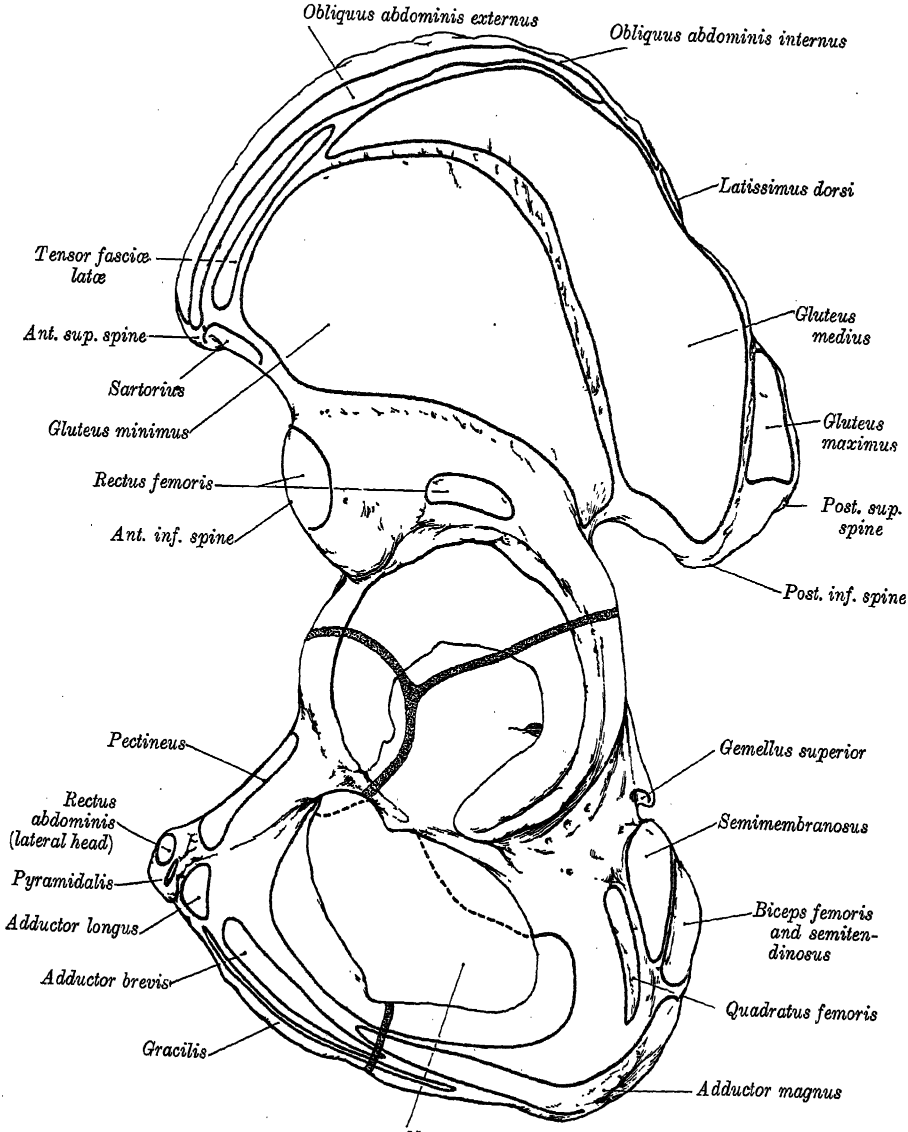


The lower portion faces inwards and is separated from the iliac fossa by the iliac part of the arcuate line. The line of union of the ilium with the ischium is completely obliterated on this surface.

Particular features.—The iliac crest forms the lower limit of the waist and gives attachment to the lateral muscles of the abdominal wall, to fasciæ and muscles of the lower limb and to muscles and fasciæ of the back (figs. 439, 441). The *outer lip* of the ventral segment (p. 368) gives attachment to the fascia lata, including the iliotibial tract; in front of the tubercle of the crest it gives origin to the tensor fasciæ latæ: in its anterior two-thirds it provides insertion for the lower fibres of the external oblique; and just behind its highest point it gives origin to the lowest fibres of the latissimus dorsi. An interval of variable size

intervenes between the posterior limit of the insertion of the external oblique and the anterior limit of the origin of the latissimus dorsi ; in this situation the crest forms the base of the lumbar triangle. The *intermediate area* gives origin to the internal oblique muscle. The *inner lip* in its anterior two-thirds gives origin to the transversus muscle ; and behind that to the lumbar fascia and the quadratus lumborum muscle. The dorsal segment (p. 368) gives origin on its lateral slope to the highest fibres of the gluteus maximus, and on its medial slope to the sacrospinalis muscle.

FIG. 439.—Key to fig. 438.



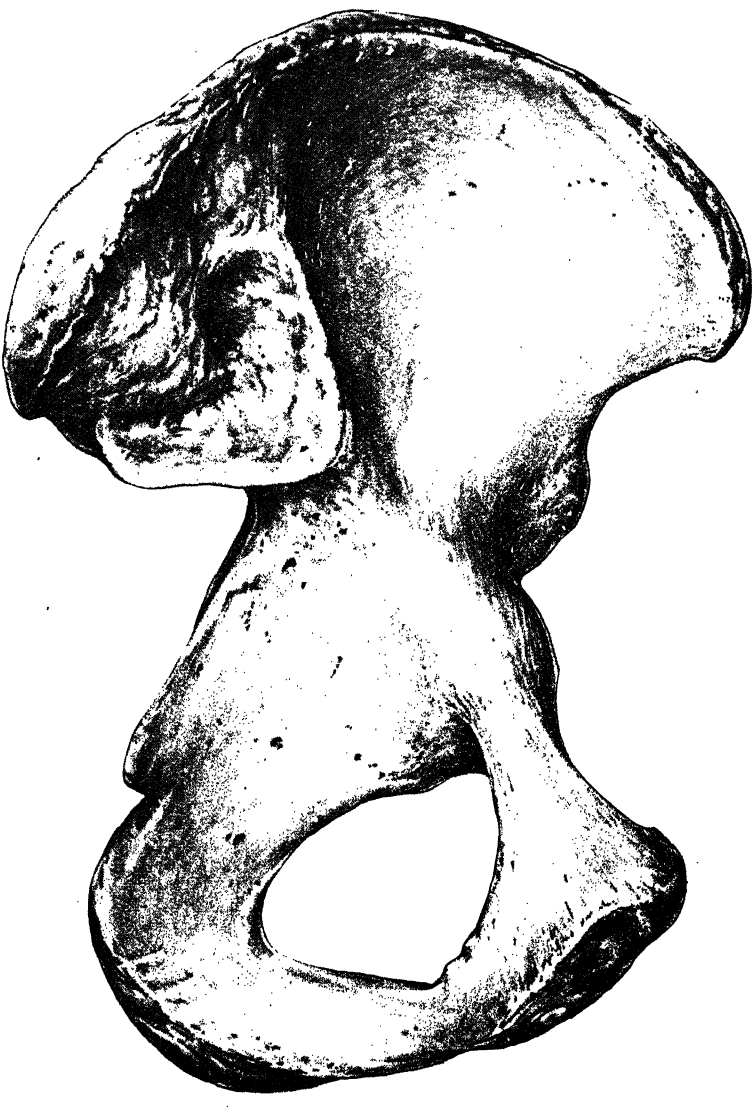
The anterior superior spine gives attachment to the lateral end of the inguinal ligament and below that to the sartorius muscle, which extends downwards for a short distance on the *anterior border*. The anterior inferior spine is divided indistinctly into two areas. The upper gives origin to the straight head of the rectus femoris and is placed on the front of the spine. The lower covers the inferior part of the spine and extends in a lateral direction along the upper margin of the acetabulum ; it is a rough impression, irregularly triangular in shape, and gives attachment to the strong iliofemoral ligament.

The upper part of the posterior border gives attachment to the upper fibres of the sacrotuberous ligament. In front of the posterior inferior spine (i.e. on the upper border of the greater sciatic notch), it gives origin to fibres of piriformis and, in front of that, is related to

the superior gluteal vessels and nerve as they emerge from the pelvis. The lower part of the posterior border (i.e. the lower margin of the greater sciatic notch) is covered by the piriformis muscle and is related to the sciatic nerve, although the nerve lies for the most part on the ischium.

The gluteal surface is divided into four areas by the three gluteal lines (fig. 438). (*a*) The area behind the posterior gluteal line gives origin in its upper roughened part to the upper

FIG. 440.—The left hip-bone. Internal surface.

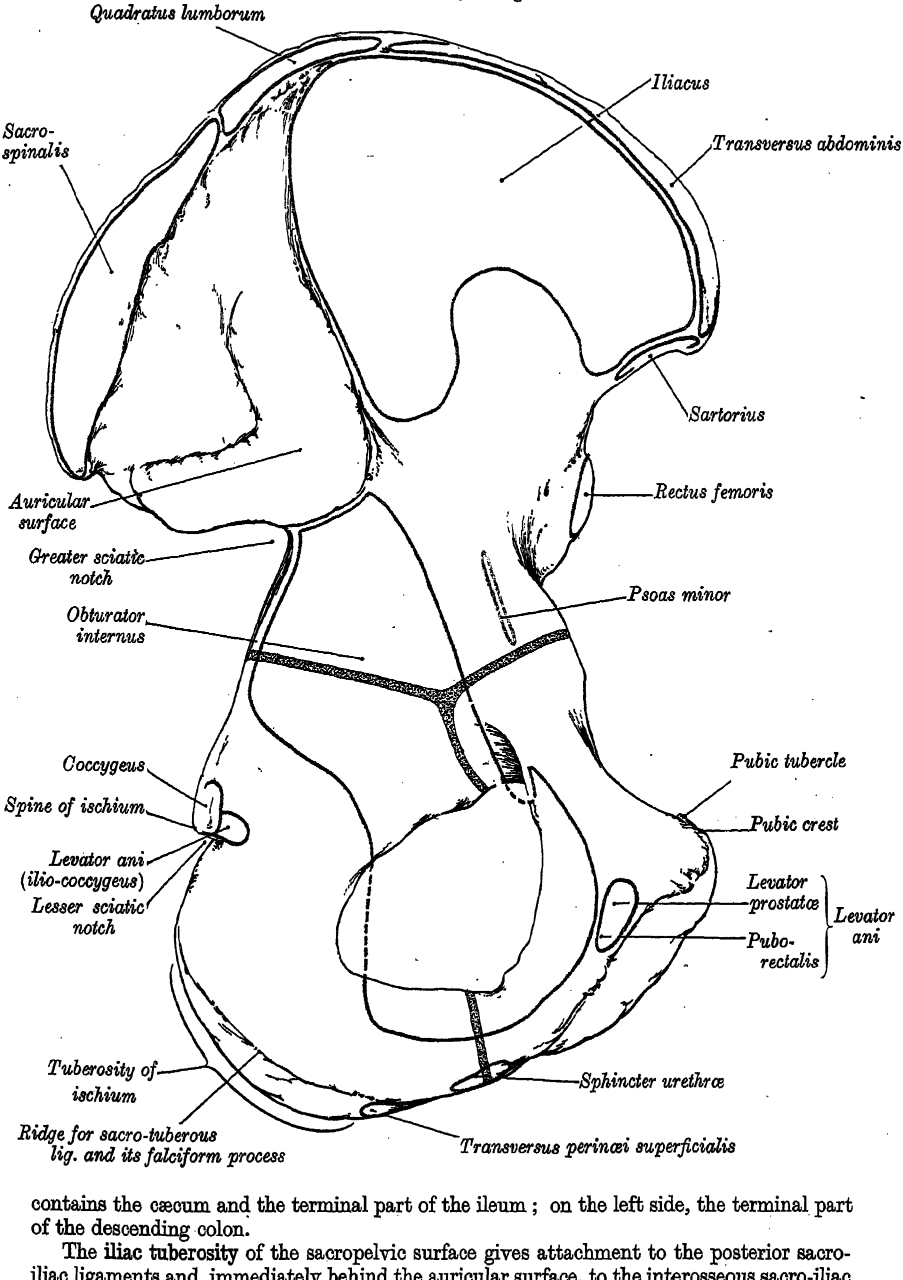


fibres of the gluteus maximus; its lower, smooth part gives attachment to some of the fibres of the sacrotuberous ligament. (*b*) The area between the posterior and middle gluteal lines, bounded above by the iliac crest, gives origin to the gluteus medius muscle. (*c*) The area between the middle and inferior gluteal lines gives origin to the gluteus minimus muscle. (*d*) The area below the inferior gluteal line is marked by numerous vascular foramina. The groove above the acetabulum gives origin to the reflected head of the rectus femoris, and the area adjoining the rim of the acetabulum affords attachment to the capsular ligament of the hip-joint. The greater part of this area is covered by the gluteus minimus muscle, but behind and below in the neighbourhood of the site of union of the ilium and ischium, the bone is related to the piriformis muscle.

The upper two-thirds of the iliac fossa provides origin for the iliacus muscle (fig. 441),

which covers the lower third but is not attached to it. Branches of the iliolumbar artery run between the muscle and the bone, and one of them enters the large nutrient foramen which is often present at the postero-inferior part of the fossa. The groove between the anterior inferior spine and the iliopubic eminence is occupied by the converging fibres of the iliacus muscle laterally and the tendon of psoas major medially; the tendon is separated from the bone near the acetabulum by its synovial bursa. On the right side the iliac fossa

FIG. 441.—Key to fig. 440.



contains the cæcum and the terminal part of the ileum; on the left side, the terminal part of the descending colon.

The **iliac tuberosity** of the sacropelvic surface gives attachment to the posterior sacro-iliac ligaments and, immediately behind the auricular surface, to the interosseous sacro-iliac ligament. The upper and anterior part of the tuberosity gives attachment to the iliolumbar ligament, and this area lies immediately below the medial part of the origin of the quadratus lumborum from the iliac crest. The **auricular surface** articulates with the upper two and a half sacral vertebræ (two only, as a rule, in the female). Its anterior and inferior borders are sharp and give attachment to the anterior sacro-iliac ligament. The upper part of the **pelvic surface**, between the inferior margin of the auricular surface and the upper

margin of the greater sciatic notch, is often marked in female subjects by a roughened groove, which is termed the *pre-auricular sulcus*; it gives attachment to the lower fibres of the anterior sacro-iliac ligament. Lateral to the sulcus the bone gives origin to fibres of the piriformis muscle. The rest of the pelvic surface gives origin to the upper half or less of the obturator internus muscle.

The pubis.—General features. The **pubis** forms the anterior part of the hip-bone and meets the pubis of the opposite side in the median plane to form a cartilaginous joint, termed the pubic symphysis. It possesses a body,* which lies anteriorly; a superior ramus, which passes upwards and backwards to the acetabulum; and an inferior ramus, which passes backwards, downwards and laterally to unite with the ramus of the ischium on the medial side of the obturator foramen.

The *body* is compressed from before backwards and presents anterior, posterior and symphyseal (or medial) surfaces and a free upper border termed the *pubic crest.* The *anterior surface* faces downwards, forwards and slightly laterally in the erect posture; rough in its upper and medial parts, it presents a smooth surface elsewhere. It is directed towards the lower limb and affords attachment for the medial group of muscles of the thigh. The *posterior surface* is smooth and faces upwards and backwards, forming the anterior wall of the true pelvis; it is related to the urinary bladder. The *symphyseal surface* is an elongated oval area, covered with cartilage in the recent state and articulating with the opposite pubis at the pubic symphysis. When denuded of cartilage it presents an irregular surface, marked by a number of small ridges and furrows or by small nodular elevations. The *pubic crest* is the rounded upper border of the body. It is projected forwards and overhangs the upper part of the anterior surface (fig. 438). Its lateral extremity forms a rounded projection termed the *pubic tubercle.* Both the crest and the tubercle can be felt through the skin in the living subject, but the latter is obscured by the spermatic cord, which crosses its upper aspect as it passes upwards from the scrotum to pierce the abdominal wall.

The *superior ramus* of the pubis springs from the upper and lateral part of the body, and passes backwards, upwards and laterally above the obturator foramen to reach the acetabulum. It is triangular on section and has three surfaces and three borders. The *pectineal surface* is directed forwards and slightly upwards. Triangular in outline, it extends from the pubic tubercle to the iliopubic eminence (fig. 438). It is bounded in front by a rounded ridge termed the *obturator crest,* and behind by a sharp edge termed the *pectineal line,* which together with the pubic crest constitutes the pubic part of the arcuate line. The *pelvic surface,* which is directed upwards, backwards and medially, is smooth and featureless; it is narrower at its lateral than at its medial extremity, where it is continuous with the posterior surface of the body. It is bounded above by the pectineal line and below by a sharp edge which forms the *inferior border.* The *obturator surface* is directed downwards and backwards, and is crossed from behind forwards and downwards by a groove termed the *obturator groove.* It is bounded in front by the obturator crest and behind by the inferior border.

The *inferior ramus* springs from the lower and lateral part of the body and passes backwards, downwards and laterally to unite with the ramus of the ischium on the medial side of the obturator foramen. The site of union may be marked by a localised thickening, but is often difficult to identify in the adult bone. The ramus has two surfaces and two borders. The *anterior* or *outer surface* is continuous above with the anterior surface of the body; it is directed towards the thigh and is roughened for muscular attachments. It is bounded laterally by the margin of the obturator foramen and medially by a rough anterior border. The *posterior* or *inner surface* is continuous above with the posterior surface of the body, and is convex from side to side. Its medial part is often prominently everted in male subjects (fig. 448) and is in contact with the crus of the penis. It is directed medially towards the perineum. Its lateral part is smooth and is directed upwards towards the pelvis.

Particular features.—The pubic tubercle gives attachment to the medial end of the inguinal ligament; it lies in the floor of the superficial inguinal ring (subcutaneous inguinal ring) and is crossed by the spermatic cord. The ascending limbs of the loops of the cre-

* The body of the pubis in the B.N.A. is the portion of the bone which takes part in the formation of the acetabulum.

master muscle are attached to the tubercle and to the anterior wall of the sheath of the rectus abdominis muscle. The lateral part of the **pubic crest** gives origin to the lateral head of the rectus abdominis, and the bone below to the pyramidalis. The medial part of the crest is crossed by the medial head of the rectus abdominis, which takes origin from an interlacement of fibres in front of the upper part of the pubis and pubic symphysis. The *anterior surface* of the body is directed towards the adductor region of the thigh. A roughened strip, usually wider in the female, marks the medial part of the surface and gives attachment to the anterior pubic ligament. In the angle between the upper end of this strip and the pubic crest the rounded tendon of the adductor longus takes origin. At a slightly lower level the gracilis arises from a linear origin close to the medial border of the body and extending downwards on to the inferior ramus. Lateral to the gracilis the adductor brevis arises from the body and the inferior ramus. The lateral part of the anterior surface, and the adjoining portions of both rami provide origin for the obturator externus muscle (fig. 439).

The **posterior surface** of the body is separated from the urinary bladder by the retropubic pad of fat. About its middle it provides origin for the anterior fibres of the levator ani muscle, and more laterally the obturator internus arises from this surface and extends on to both rami. Medial to the origin of the levator ani, the puboprostatic ligaments are attached to the bone.

The *pectineal surface* of the **superior ramus** gives origin, along its upper part, to the pectineus muscle, which covers the rest of the surface (fig. 439) but is not attached to it. The **pectineal line**, which forms the upper boundary of the pectineal surface, is a salient, sharp ridge. At its medial end it gives attachment to the conjoint tendon (falx inguinalis aponeurotica) and the pectineal part of the inguinal ligament (lacunar ligament), and throughout the rest of its extent it affords attachment to a strong fibrous band termed the pectineal ligament (p. 564). About its middle it receives the insertion of the psoas minor. The *pelvic surface* is smooth and is not covered with muscle or fascia. It is separated from the parietal peritoneum only by the intervening subperitoneal tissue, in which the lateral umbilical ligament (obliterated hypogastric artery) runs downwards and forwards across the ramus and, near its lateral end, the vas deferens passes backwards. The *obturator groove* on the obturator surface is converted into a canal by the upper borders of the obturator membrane, the obturator internus and the obturator externus muscles. It transmits the obturator vessels and nerve from the pelvis to the thigh, where they emerge under cover of the pectineus muscle. The *obturator crest* (fig. 438) at its lateral end gives attachment to some of the fibres of the pubofemoral ligament.

The *outer surface* of the **inferior ramus** gives origin to the gracilis, the adductor brevis and the obturator externus, named from the medial to the lateral side. In addition, the origin of the adductor magnus usually extends from the ramus of the ischium on to the lower part of the inferior ramus of the pubis in the interval between the adductor brevis and the obturator externus. The *inner surface* is divided into a medial, an intermediate and a lateral area, but they are not separated from one another by clear-cut markings on the bone. The medial area faces downwards and medially and is in direct contact with the crus penis; it is limited above and behind by an indistinct ridge which gives attachment to the perineal membrane (inferior fascia of the urogenital diaphragm). The intermediate area gives origin to the sphincter urethræ muscle. The lateral area gives origin to fibres of the obturator internus muscle. The *medial margin* of the ramus is strongly everted in the male and gives attachment to the fascia lata and to the membranous layer of the superficial fascia of the perineum.

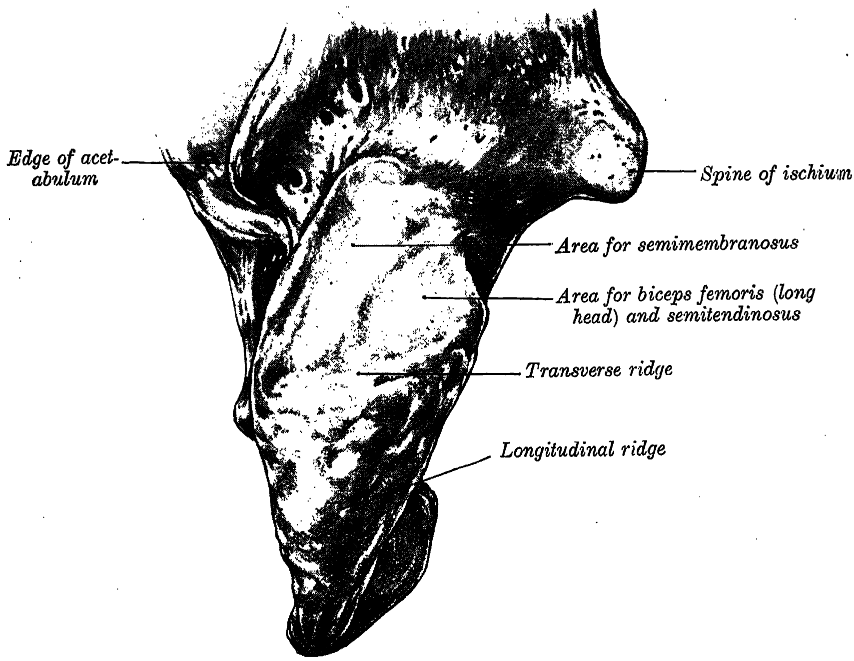
The ischium.—General features.—The **ischium** forms the lower and posterior part of the hip-bone. It comprises a body and a ramus. The body has upper and lower extremities, and femoral, dorsal and pelvic surfaces.

The *upper extremity* forms the lower part of the acetabulum and is fused with the ilium and pubis. The *lower extremity* is free and is capped by the lower part of a large bony prominence, termed the *ischial tuberosity.* The ramus springs from the front of the lower part of the body.

The *femoral surface* of the body is directed downwards, forwards and laterally towards the thigh. It is roughened and uneven, and is bounded in front by the margin of the obturator foramen, and laterally by the lateral border, which is indistinct above but clearly defined below, where it forms the lateral border of the ischial tuberosity. The *dorsal surface* is directed backwards, laterally and upwards. Above, it is continuous with the lower part of the gluteal surface of the ilium, and where the two elements meet the bone presents a low convexity, which corresponds with the curvature of the posterior part of the acetabulum. Below, the surface is marked by the upper part of the ischial tuberosity. Above the tuberosity the bone presents a wide and shallow groove both on the lateral and on the medial side. The *ischial tuberosity* is a large, roughened impression which marks the lower part

of the posterior surface and the inferior extremity of the body of the ischium. It is an elongated area, widest near its upper end and tapering away inferiorly, and provides attachment for some of the large muscles of the thigh. The posterior surface is placed between the lateral and the posterior borders of the body. The *posterior border* is continuous above with the posterior border of the ilium and helps it to complete the lower margin of the greater sciatic notch. The posterior end of that margin is marked by a conspicuous projection termed the *ischial spine*. Below the spine the border becomes rounded and indefinite, forming the floor of a rounded notch, termed the lesser sciatic notch, which lies between the ischial spine and the tuberosity. The *pelvic surface* is smooth and relatively featureless and is directed towards the pelvic cavity; its lower portion forms part of the lateral wall of the ischiorectal fossa in the perineum.

FIG. 442.—The left ischial tuberosity, viewed from behind and below.



The *transverse ridge* forms the lower boundary of the area for the hamstring muscles and separates it from the lower half of the tuberosity, which is divided into lateral and medial areas by the *longitudinal ridge*. The lateral area gives origin to the adductor magnus; the medial area is covered with fibro-fatty tissue and supports the body in the sitting posture.

The *ramus* of the ischium springs from the lower part of the front of the body and passes upwards, forwards and medially to meet the inferior ramus of the pubis, forming the lower boundary of the obturator foramen. It presents anterior (or outer) and posterior (or inner) surfaces, continuous with the corresponding surfaces of the inferior pubic ramus. The *anterior surface* is directed forwards and downwards towards the thigh and is rough for the attachment of the medial femoral muscles. The *posterior surface* is smooth, and partly subdivided into a perineal and a pelvic area, like the inferior ramus of the pubis. The *upper border* helps to complete the margin of the obturator foramen; the *lower border* is roughened and free, and together with the medial border of the inferior ramus of the pubis forms the lateral boundary of the subpubic angle and part of the pubic arch.

Particular features.—The *femoral surface* of the body of the ischium gives origin below to a part of the obturator externus muscle and along the lateral border of the upper part of the ischial tuberosity to the quadratus femoris. The upper part of this surface is pitted by numerous vascular foramina and is covered by the tendon of the obturator externus as it passes laterally and backwards in the groove between the acetabulum and the ischial tuberosity. Just below the acetabulum the lateral border gives attachment to the ischiofemoral ligament.

Immediately above the ischial tuberosity the *dorsal surface* is crossed by the tendon of the obturator internus and the gemelli muscles; the nerve to the quadratus femoris intervenes between these structures and the bone as it descends to reach its destination. At a higher level, the bone is covered with the piriformis muscle, which is partially separated from it by the sciatic nerve and the nerve to the quadratus femoris. The **ischial tuberosity** is divided by a nearly transverse ridge into an upper and a lower area. The upper area is associated with the hamstring muscles; it is divided by an oblique line into an upper and lateral part which gives origin to the semimembranosus, and a lower and medial part from which the long head of the biceps femoris arises in common with the semitendinosus muscle. The lower portion of the tuberosity narrows as it passes forwards on to the lower end of the ischium. It is divided into a lateral and a medial area; the lateral area is the larger and affords origin to part of the adductor magnus muscle; the medial area is covered by fibro-fatty tissue, which usually contains the ischial bursa of the gluteus maximus. It is the medial area on the lower part of the tuberosity which supports the body in the sitting posture. On its medial side the tuberosity is limited by a curved ridge which extends forwards on to the ramus of the ischium and gives attachment to the sacrotuberous ligament and its falciform process (fig. 441). Many of the fibres of origin of the biceps femoris can be traced into the sacrotuberous ligament, and this intimate relationship is noteworthy, for the sacrum and the posterior part of the ilium constitute the primitive mammalian origin of the biceps femoris. The origin of the muscle from the tuberosity in man is secondary and the sacrotuberous ligament represents the remains of its primitive tendon of origin.

Above and medial to the tuberosity the posterior surface presents a wide, shallow groove. In this situation the bone is usually covered with a thin layer of cartilage in the recent state and a bursa is interposed between it and the tendon of the obturator externus, which lies in the groove. The lower margin of the groove, close to the tuberosity, gives origin to the inferior gemellus; the upper margin of the groove, close to the ischial spine, gives origin to the superior gemellus.

The **ischial spine** projects downwards and medially. Its margins give attachment to the sacrospinous ligament, which separates the greater sciatic foramen from the lesser (fig. 540). Its dorsal surface is crossed by the internal pudendal vessels and the nerve to obturator internus, as they lie in the gluteal region. The pelvic surface of the spine gives origin to the coccygeus and the most posterior fibres of the levator ani muscle. The structures transmitted by the greater and lesser sciatic foramina are described on p. 481.

The *pelvic surface* of the body of the ischium is smooth. Its upper part gives origin to the obturator internus muscle, the fibres of which converge on the lesser sciatic notch and cover the remainder of this surface, with the exception of the pelvic aspect of the ischial spine. The muscle and its covering fascia separate the bone from the ischiorectal fossa.

The *anterior surface* of the **ramus of the ischium** is directed towards the adductor region of the thigh. It gives origin to the obturator externus above, the anterior fibres of the adductor magnus and, near the lower border, to the gracilis muscle. Between the adductor magnus and the gracilis the origin of the adductor brevis may extend downwards from the inferior ramus of the pubis for a short distance. The *posterior surface* is divided into pelvic and perineal areas. The pelvic area is directed upwards and backwards and gives origin to part of the obturator internus. The perineal area is directed medially; its upper part is related to the crus of the penis and gives origin to the sphincter urethræ; its lower part gives origin to the ischiocavernosus and to the superficial transversus perinei muscles. The perineal membrane is attached to the ridge which separates the perineal from the pelvic area below, and the area for the crus from the origin of the sphincter urethræ above. The *lower border* of the ramus provides attachment for the fascia lata of the thigh and the membranous layer of the superficial fascia of the perineum.

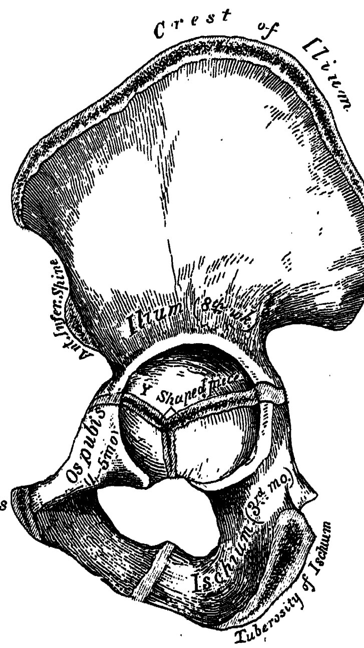
The **acetabulum** (fig. 438) is a deep cup-shaped cavity on the lateral aspect of the hip-bone about its centre, and is directed laterally, downwards and forwards. It is surrounded by an irregular projecting margin which is deficient inferiorly; this gap is termed the *acetabular notch.* The floor of the cavity is roughened and non-articular and is termed the *acetabular fossa.* The sides of the cup present a horseshoe-shaped *articular surface* which is widest superiorly; in this situation the weight of the trunk is transmitted to the femur in the erect attitude. In the recent state this strip is covered with articular cartilage and provides the surface on which the head of the femur moves within the hip-joint. All three elements of the hip-bone contribute to the formation of the acetabulum in man, but not in equal proportions. The pubis forms the upper and anterior fifth of the articular surface; the ischium, the floor of the acetabular fossa and rather more than the lower and posterior two-fifths of the articular surface; the ilium forms the remainder of the articular surface.

The **obturator foramen** is a large gap in the hip-bone, below and in front of the acetabulum and placed between the pubis and the ischium. It is bounded

above by the grooved obturator surface of the superior ramus of the pubis; medially by the body and inferior ramus of the pubis; below by the ramus of the ischium; and laterally by the anterior border of the body of the ischium, including the margin of the acetabular notch. The foramen is occupied in the recent state by a fibrous sheet, termed the obturator membrane, which is attached to its margins except above, where a communication is left between the pelvis and the thigh. The free upper edge of the membrane is attached in front to the *anterior obturator tubercle*, which marks the anterior end of the inferior border of the superior ramus of the pubis, and behind to the *posterior obturator tubercle*, which is placed on the anterior border of the acetabular notch. These tubercles are not always easy to identify. The foramen is large and oval in the male, but is smaller and nearly triangular in the female.

FIG. 443.—A plan of the ossification of the hip-bone.

By eight centres { *Three primary, for the ilium, ischium, and pubis.* / *Five secondary.* }



Symphysis pubis

The three primary centres unite through the Y-shaped piece about puberty.
Secondary centres appear about puberty, and unite about 25th year.

Structure.—The thicker parts of the hip-bone consist of spongy substance, enclosed between two layers of compact bone; the thinner parts, as at the bottom of the acetabulum and centre of the iliac fossa, are usually semitransparent, and composed entirely of compact bone. At the upper part of the acetabulum and along the arcuate line, i.e. along the line of weight transmission from the sacrum to the head of the femur, the amount of compact bone shows a considerable increase. In this situation the underlying spongy substance shows the presence of two sets of pressure lamellæ. The first arise near the upper part of the auricular surface and diverge to impinge on two stout buttresses formed by the compact bone. From there two similar sets of lamellar arches take origin and converge on the acetabulum.*

Ossification (fig. 443).—The hip-bone is ossified from eight centres: three primary, one each for the ilium, ischium, and pubis; and five secondary, one each for the iliac crest, the anterior inferior iliac spine (said to occur more frequently in the male than in the female), the tuberosity of the ischium, the pubic symphysis (more frequent in the female than in the male), and one

* C. P. G. Wakeley, *Proceedings of Anatomical Society, Journal of Anatomy*, vol. lxiv. 1929.

or more for the Y-shaped cartilage at the bottom of the acetabulum. The centres appear in the following order: in the ilium, immediately above the greater sciatic notch, about the eighth or ninth week of intrauterine life; in the body of the ischium, about the third month; in the superior ramus of the os pubis, between the fourth and fifth months. At birth, the iliac crest, the greater part of the acetabulum, the ischial tuberosity, and the inferior ramus of the pubis and the ramus of the ischium are cartilaginous. By the seventh or eighth year, the inferior ramus of the pubis and the ramus of the ischium are almost completely united by bone. The three primary centres extend their growth into the bottom of the acetabulum, where they are separated from each other by a Y-shaped portion of cartilage, which begins to ossify from two or more centres in the twelfth year. One of these centres, named the *os acetabuli*, forms a triangular scale of bone over the acetabular part of the pubis and fuses with the main parts of the bone about puberty. The ilium and ischium then become joined, and lastly the pubis and ischium, through the medium of this Y-shaped portion. At about the age of puberty, ossification takes place in each of the remaining portions, and they join with the rest of the bone between the twentieth and twenty-fifth years. Separate centres are frequently found for the pubic tubercle, crest and angle, and for the ischial spine.

Comparison of the girdles of the upper and lower limbs.—The importance of mobility in the upper limb as contrasted with the necessity for stability in the lower limb is well illustrated by the more obvious differences which exist between the two girdles.

Girdle of Upper Limb.	*Girdle of Lower Limb.*
(*a*) Consists of two separate bones, viz., the scapula and the clavicle.	(*a*) Consists of a single bone, viz., the hip-bone.
(*b*) Reaches the axial skeleton only at the sternoclavicular joint.	(*b*) Articulates with the vertebral column at the sacro-iliac joint.
(*c*) Is not directly connected to its fellow of the opposite side, except by the interclavicular ligament.	(*c*) Articulates with its fellow of the opposite side at the pubic symphysis.
(*d*) Has a shallow fossa for the head of the humerus.	(*d*) Has a deep cup for the head of the femur.

THE PELVIS

The **pelvis**, so called from its resemblance to a basin, is a massive bony ring interposed between the movable segments of the vertebral column, which it supports, and the lower limbs, upon which it rests; it is composed of the two hip-bones laterally and in front, and the sacrum and coccyx behind. It is divided into the false (greater) and the true (lesser) pelvis by an oblique plane passing through the prominence of the sacrum behind, and the arcuate line on each side and in front. These two subdivisions communicate with each other through the *pelvic inlet*.

The **false pelvis (greater pelvis)**, the expanded portion of the cavity above and in front of the pelvic inlet, is bounded on each side by the ilium and posteriorly by the base of the sacrum.

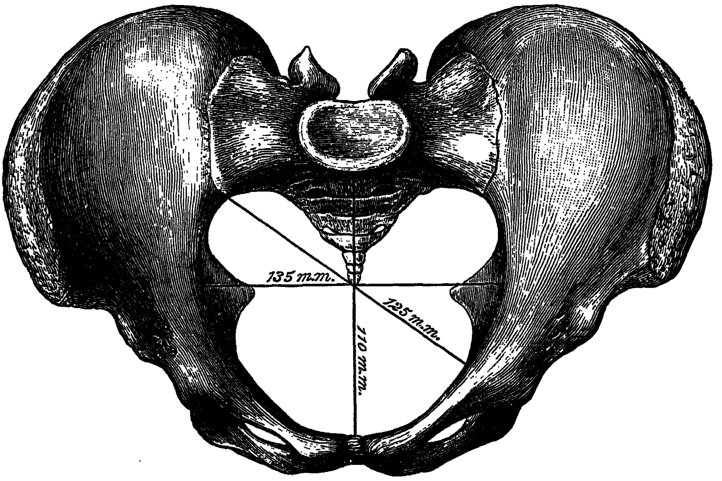
The **true pelvis (lesser pelvis)** is that part of the pelvic cavity which lies below and behind the pelvic inlet. Its bony walls are more complete than those of the false pelvis. It possesses an inlet, an outlet and a cavity.

The bony boundaries of the pelvic inlet constitute the *brim* of the pelvis (fig. 444). The inlet is somewhat heart-shaped, obtusely pointed in front, and encroached upon behind by the forward projection of the promontory of the sacrum. It has three principal diameters: anteroposterior, transverse, and oblique. The *anteroposterior* or *conjugate diameter* extends from the lumbosacral angle to the symphysis pubis; its average measurement is about 110 mm. in the female. The *transverse diameter* extends from the middle of the brim on one side to the same point of the opposite side; its average measurement is about 135 mm. in the female. The *oblique diameter* extends from the iliopubic (iliopectineal) eminence

to the opposite sacro-iliac joint; its average measurement is about 125 mm. in the female.

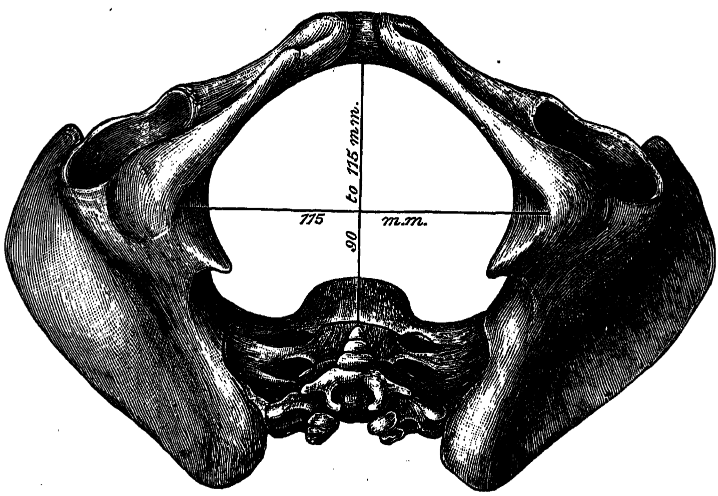
The *cavity* of the true pelvis is a short curved canal, considerably deeper behind than in front. It is bounded in front and below by the pubic rami and symphysis;

FIG. 444.—The diameters of the inlet of the true pelvis (female).



above and behind, by the pelvic surfaces of the sacrum and coccyx; laterally by a smooth, quadrangular area of bone, formed by the pelvic surfaces of the ilium and ischium. It contains, in the recent subject, the pelvic colon, rectum, urinary bladder, and some of the organs of generation. The rectum is placed at the back of the pelvis, in the curve of the sacrum and coccyx; the urinary bladder is in front,

FIG. 445.—The diameters of the outlet of the true pelvis (female).



behind the pubic symphysis. In the female, the uterus and vagina lie between the rectum and the urinary bladder.

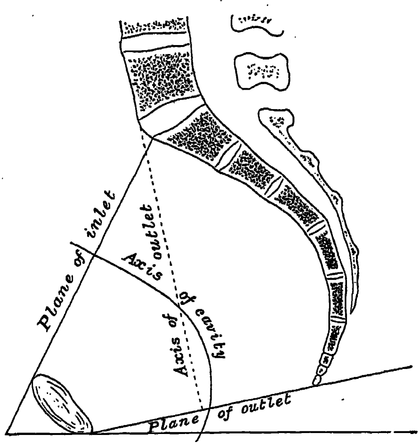
The *outlet* is very irregular in shape (fig. 445) and is bounded behind by the apex of the coccyx, and laterally by the ischial tuberosities. These eminences are separated by three notches: one in front—the *pubic arch*—formed by the convergence of the rami of the ischium and pubis on each side. The other notches, one on each side, are formed by the sacrum and coccyx behind, the ischium in front, and the ilium above: they are called the *sciatic notches*; in the natural state they are converted into foramina by the sacrotuberous and sacrospinous ligaments. When

these ligaments have been preserved, the outlet of the pelvis is lozenge-shaped, and is bounded, in front, by the inferior pubic ligament and the inferior rami of the pubic bones and the ischial rami; laterally, by the ischial tuberosities; behind, by the sacrotuberous ligaments and the tip of the coccyx.

The *anteroposterior diameter* of the outlet of the pelvis extends from the apex of the coccyx to the lower part of the pubic symphysis; its measurement is from 90 to 115 mm. in the female. It varies with the length of the coccyx, and is capable of increase or diminution, on account of the mobility of that bone. The *transverse diameter*, measured across the widest part of the outlet, is about 115 mm. in the female.*

Axes (fig. 446).—The axis of the inlet, i.e. a line at right angles to the plane of the inlet through its centre, is directed downwards and backwards, and if the line is prolonged it passes through the umbilicus above and the middle of the coccyx below. The axis of the outlet is directed downwards and slightly backwards; if prolonged upwards it touches the base of the sacrum. The axis of the cavity—i.e. an axis at right angles to a series of planes between and including those of the inlet and outlet—is curved like the cavity itself: this curve is parallel with that of the sacrum and coccyx.

Fig. 446.—A median sagittal section through the pelvis.



Position of the pelvis (fig. 446).—In the erect posture, the pelvis is placed obliquely with regard to the trunk: the plane of the inlet forms with the horizontal plane an angle of from 50° to 60°, and that of the outlet one of about 15°. The pelvic surface of the pubic symphysis looks upwards and backwards, the concavity of the sacrum and coccyx downwards and forwards. The position of the pelvis in the erect posture may be demonstrated by holding it so that the anterior superior iliac spines and the front of the top of the pubic symphysis are in the same vertical plane.

In the sitting posture the body rests on the medial and lower parts of the ischial tuberosities (p. 377), and a coronal plane drawn through the anterior superior iliac spines passes through the acetabula. The lumbosacral angle is considerably reduced and the projection of the sacral promontory is correspondingly diminished.

Differences between the male and female pelves (figs. 447, 448, 449, 450).—Sexual characters are more pronounced in the bones of the pelvis than in any other bones in the body. The female pelvis is specially adapted to facilitate the passage of the fœtal head during parturition and it must therefore provide more accommodation than is necessary in the male pelvis, while its depth must be diminished. The essential differences were well summed up by Arthur Thomson, who described the male pelvis as a long section of a short cone and the female pelvis as a short section of a long cone. There are, however, very many differences in detail, most of which can be referred to these fundamental distinctions.

As a whole, the bones of the female pelvis are more delicate and their muscular impressions are not so well marked. The ilia are more vertical and, although the distance between the iliac crests is less in the female, the anterior superior iliac spines are farther apart. As a rule, the iliac fossæ are shallower and the curves of the crest, as seen from above, are not so pronounced. The prominence of the hips in the female may be attributed, in part, to the sexual characters of the ilium.

The inlet of the true pelvis is larger in the female and is more nearly circular in outline: in the male it is typically heart-shaped.

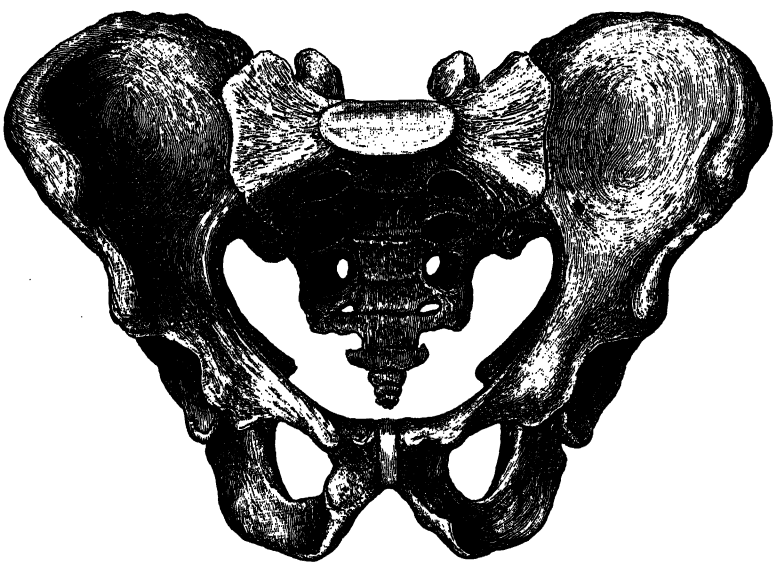
* The measurements of the pelvis given above are fairly representative, but different figures are given by various authors, no doubt mainly due to difference in the physique and stature of the population from whom the measurements have been taken.

The cavity of the female pelvis is wider and shallower, and, in the production of this general difference, the following factors are to be noted. (1) The sacrum is shorter and wider in the female and its upper part is straight (p. 223). (2) The depth of the pubic symphysis is less and the distance between the two pubic tubercles is greater in the female. (3) The sciatic notches are wider and shallower,

FIG. 447.—The female pelvis. Anterior aspect.

From a specimen in the museum of the Royal College of Surgeons of England.

FIG. 448.—The male pelvis. Anterior aspect.



and the spines of the ischia do not project inwards to the same extent as they do in the male.

The outlet is larger in the female, since (1) the pubic arch is wider and more rounded and it will always admit a set square: whereas in the male it is more pointed and definitely less than a right angle; (2) the ischial tuberosities are more everted; and (3) the coccyx is more movable.

The male pelvis possesses one positive sexual character: the margins of the pubic arch are more everted, owing to the larger size of the crura of the penis.

The following additional differences should also be mentioned. (1) The acetabula are smaller in the female: they are wider apart and look more definitely forwards.* As a result the transverse diameter of the acetabulum is distinctly less than the distance from its anterior margin to the pubic symphysis. In the male, on the other hand, the two measurements are practically equal. (2) The obturator foramen is smaller in the female and is triangular in shape. In the male it is more oval in outline, but this difference is not of great value as a sexual character. (3) The pre-auricular sulcus (p. 374) is more constantly present in the female ilium, and its presence is presumably associated with the existence of a more movable sacro-iliac joint. (4) The auricular surface of the sacrum is limited to the first and second sacral vertebræ in the female, but in the male it usually extends to the middle of the third vertebra.

The size of the pelvis varies not only in the two sexes, but also in different members of the same sex, and does not appear to be greatly influenced by the height of the individual. Women of short stature, as a rule, have broad pelves. Occasionally the pelvis is contracted in all its dimensions, and its diameters may be as much as 12·5 mm. less than the average, and this even in well-formed women of average height. The principal divergences, however, are found at the inlet, and affect the relation of the anteroposterior to the transverse diameter. Thus the inlet may be elliptical either in a transverse or an anteroposterior direction, the transverse diameter in the former, and the anteroposterior in the latter, greatly exceeding the other diameters; in some instances it is almost circular.

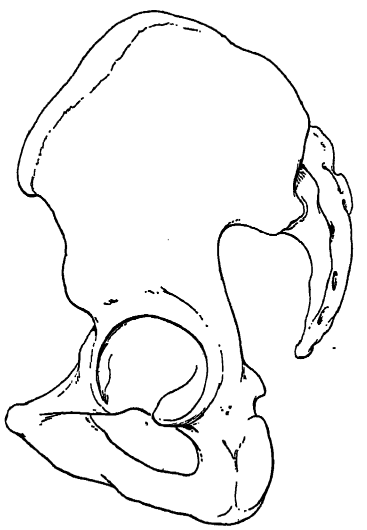


FIG. 449.—Profile view of male pelvis.

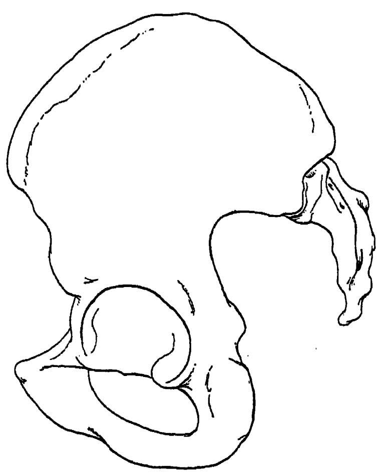


FIG. 450.—Profile view of female pelvis.

In the *fœtus*, and for several years after birth, the pelvis is small in proportion to that of the adult, and the projection of the lumbosacral angle less marked. The characteristic differences between the male and female pelves are distinctly indicated as early as the fourth month of intrauterine life.

THE FEMUR (figs. 453–456)

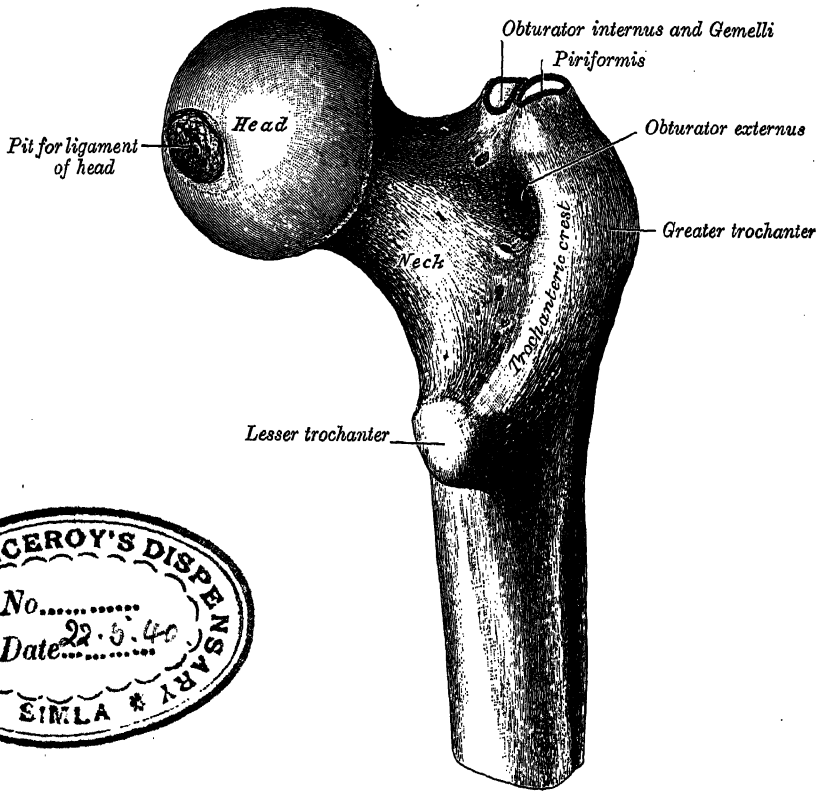
The **femur**, or thigh-bone, is the longest and strongest bone in the body. It possesses a shaft and two extremities. The shaft is almost cylindrical in most of its length, and is curved with a *forward convexity*. The head, which is rounded, can easily be distinguished from the widely expanded lower end: it projects from the *medial* side of the *upper* end of the shaft. This information is sufficient to enable the student to assign a given femur correctly to its appropriate side of the body.

In the erect posture the femora are placed obliquely (fig. 261). Their heads

* Derry, *Journal of Anatomy and Physiology*, vol. xliii.

are separated by the breadth of the true pelvis and their shafts incline downwards and medially, so that the medial sides of the two knees can just touch. As the bones of the legs descend vertically from the knees, the obliquity of the femoral shafts results in the approximation of the feet in the erect attitude and the provision of a narrow base for the support of the weight of the body. The narrowness of the base detracts from the stability of the body but greatly facilitates movements and increases the speed with which they can be executed. The degree of obliquity of the shafts varies in different individuals, but is usually greater in women on account of the greater breadth of the pelvis.

Fig. 451.—The upper part of the right femur. Viewed from behind.



The **upper end** of the femur (fig. 451) comprises a head, a neck, a greater and a lesser trochanter.

General features.—The **head** forms rather more than half a sphere; it is directed upwards, medially and slightly forwards, to articulate with the acetabulum of the hip-bone. Its surface is smooth, and is marked a little below and behind its centre by a small roughened pit.

The **neck** of the femur, which is about 5 cm. long, connects the head and the shaft, with which it forms an angle of about 125°. The arrangement facilitates the movements of the hip-joint and enables the lower limb to swing clear of the pelvis. The neck is narrowest at its middle and is wider at its lateral than at its medial end. Its two borders are rounded. The upper border is nearly horizontal and is gently concave upwards. The lower border is straight but oblique, and is directed downwards, laterally and backwards to meet the shaft near the lesser trochanter. The anterior surface of the neck is flattened and its junction with the shaft is marked by a prominent rough ridge termed the *trochanteric line*. The posterior surface is convex backwards and upwards in its transverse axis, and concave in its long axis, and its junction with the shaft is marked by a rounded ridge termed the *trochanteric crest*.

Fig. 1.—Radiograph of the hand and wrist of a child aged 2½ years. The capitate and hamate bones are in process of ossification, but the other carpal bones are still cartilaginous. The centre for the head of the ulna has not yet appeared, but the centre for the lower epiphysis of the radius is present. Note the condition of the metacarpal bones and phalanges.

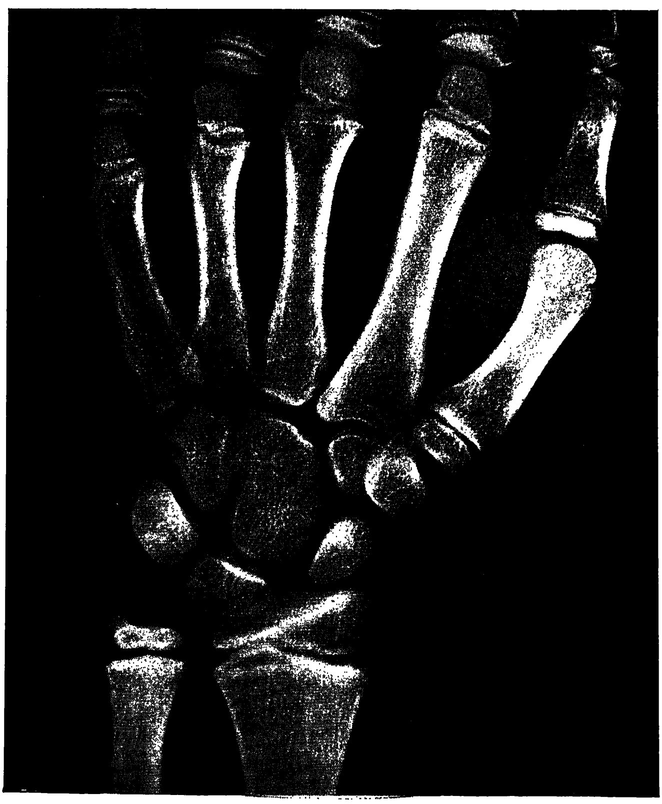


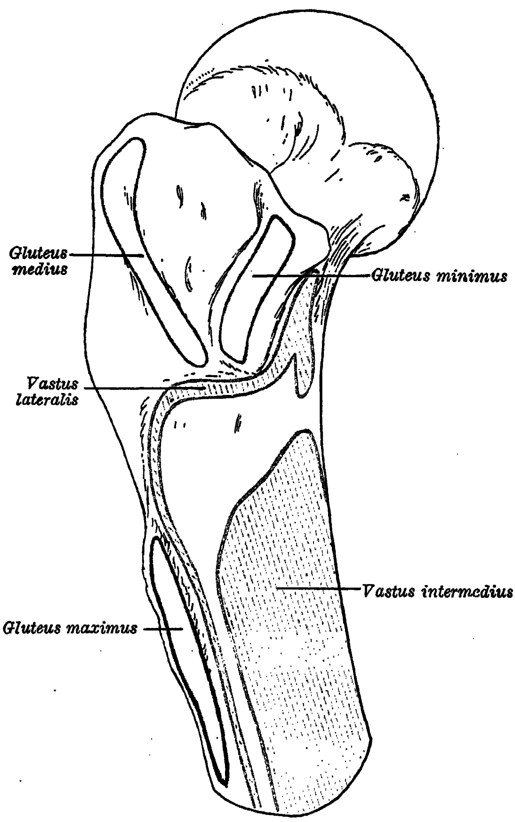
Fig. 2.—Radiograph of hand and wrist of a child aged 11 years. All the centres of ossification are present except that for the pisiform bone. Note how the first metacarpal differs from the other metacarpal bones.

FIG. 1.—Radiograph of an adult pelvis. The upper arrow indicates the line of the sacro-iliac joint; the lower arrow points to the anterior inferior iliac spine.

FIG. 2.—Radiograph of the pelvis of a child aged $3\frac{1}{2}$ years. The epiphysis for the head of the femur is well formed, but the centre for the greater trochanter has not yet appeared. The rami of the pubis and ischium are still connected by cartilage and the triradiate cartilage in the acetabulum is wide.

The **greater trochanter** is a large, quadrangular eminence, situated at the upper part of the junction of the neck with the shaft. Its posterosuperior portion projects upwards and medially (fig. 455) so as to overhang the adjoining part of the posterior surface of the neck; in this situation its medial surface presents a roughened, depressed area, termed the *trochanteric fossa.* The upper border of the trochanter lies one hand's-breadth below the tubercle on the iliac crest, and is on a level with the centre of the head of the femur. The anterior surface of the trochanter presents a roughened impression; its lateral surface is divided into two areas by an oblique, flattened strip, wider above than below, which runs downwards and forwards across it. The lateral surface of the trochanter can be palpated in the living subject, and, when the adjoining muscles are relaxed, the trochanter can be gripped between the thumb and fingers.

Fig. 452.—The upper part of the right femur. Lateral aspect.



The **lesser trochanter** (fig. 451) is a conical eminence, which projects medially and backwards from the shaft at its junction with the lower and posterior part of the neck. Its summit and anterior surface bear a roughened impression, but its posterior surface, which lies at the lower end of the trochanteric crest, is smooth and even. It is placed too deeply to be felt in the living subject.

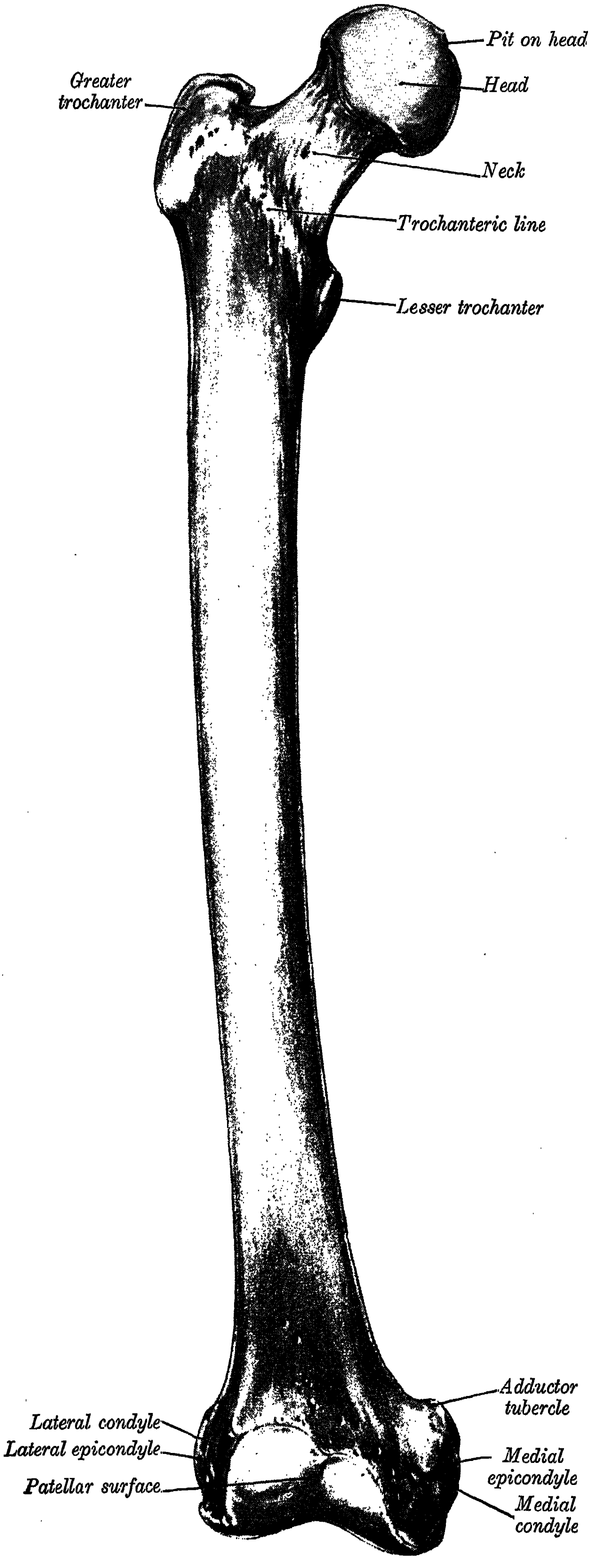
The *trochanteric line* marks the junction of the anterior surface of the neck with the shaft of the femur (fig. 453). It is a prominent roughened ridge, which commences in a tubercle at the upper and medial part of the anterior surface of the greater trochanter and runs downwards and medially. It reaches the lower border of the neck on a level with the lesser trochanter, but in front of it. Below, it is continuous with the *spiral line* (p. 388).

The *trochanteric crest* (fig. 455) marks the junction of the posterior surface of the neck with the shaft of the femur. It is a smooth rounded ridge, which commences at the posterosuperior angle of the greater trochanter and runs downwards and medially to terminate at the lesser trochanter. A little above its middle it presents a low rounded elevation, sometimes termed the *quadrate tubercle.*

Particular features.—The head of the femur is entirely intracapsular and is encircled immediately lateral to its greatest diameter by the labrum acetabulare. Its circumference is sharply defined, except on the anterior surface, where the cartilage covered surface extends on to the front of the neck. The pit which marks the head below and behind its centre (fig. 451) gives attachment to the ligament of the head of the femur (ligamentum teres). The inferomedial part of the anterior surface of the head is related to the femoral artery, from which it is separated by the tendon of the psoas major and the articular capsule.

The neck of the femur is marked by numerous vascular foramina, especially on its anterior surface and on the upper part of its posterior surface. The angle which it makes with the shaft is widest at birth and diminishes steadily until the adult condition is reached. It is less in the female than in the male, owing to the increased breadth of the true pelvis and the greater obliquity of the shaft of the femur. The *anterior surface* of the neck

FIG. 453.—The right femur. Anterior aspect.



is entirely intracapsular and on this surface the capsular ligament extends laterally to the trochanteric line. On the *posterior surface* the capsular ligament does not reach the trochanteric crest (fig. 456), and only a little more than the medial half of the neck lies within the capsule. The part of the anterior surface adjoining the head is covered with cartilage and is related to the iliofemoral ligament in the erect posture. A faint groove crosses the posterior surface in an upward and lateral direction; it is produced by the obturator externus tendon as it passes to the trochanteric fossa. The neck of the femur does not lie in the same plane as the shaft, but is carried forwards as it passes upwards and medially. On this account the transverse axis of the head of the femur makes an angle with the transverse axis of the lower end of the bone, and this angle is known as the angle of femoral *torsion*.

The **greater trochanter** (fig. 452) provides insertion for most of the muscles of the gluteal region. The gluteus minimus is inserted into the rough impression on its anterior surface. The gluteus medius is inserted into the oblique, flattened strip, which runs downwards and forwards across its lateral surface. The area in front of this insertion is separated from the tendon by the trochanteric bursa of the gluteus medius; the area behind the insertion is covered by the deep fibres of the gluteus maximus, and a portion of the trochanteric bursa of that muscle may be interposed. The upper border of the trochanter gives insertion to the piriformis, and its medial surface to the common tendon of the obturator internus and the two gemelli. At their insertions these two tendons are frequently blended with each other. The trochanteric fossa receives the insertion of the obturator externus.

The **lesser trochanter** receives the insertion of the psoas major on its summit and on the medial part of its anterior surface. The base of the trochanter is expanded and its medial or anterior surface gives

insertion to the iliacus, which extends downwards for a short distance behind the spiral line. The upper fibres of the adductor magnus play over the posterior surface of the lesser trochanter and a bursa is sometimes interposed between them.

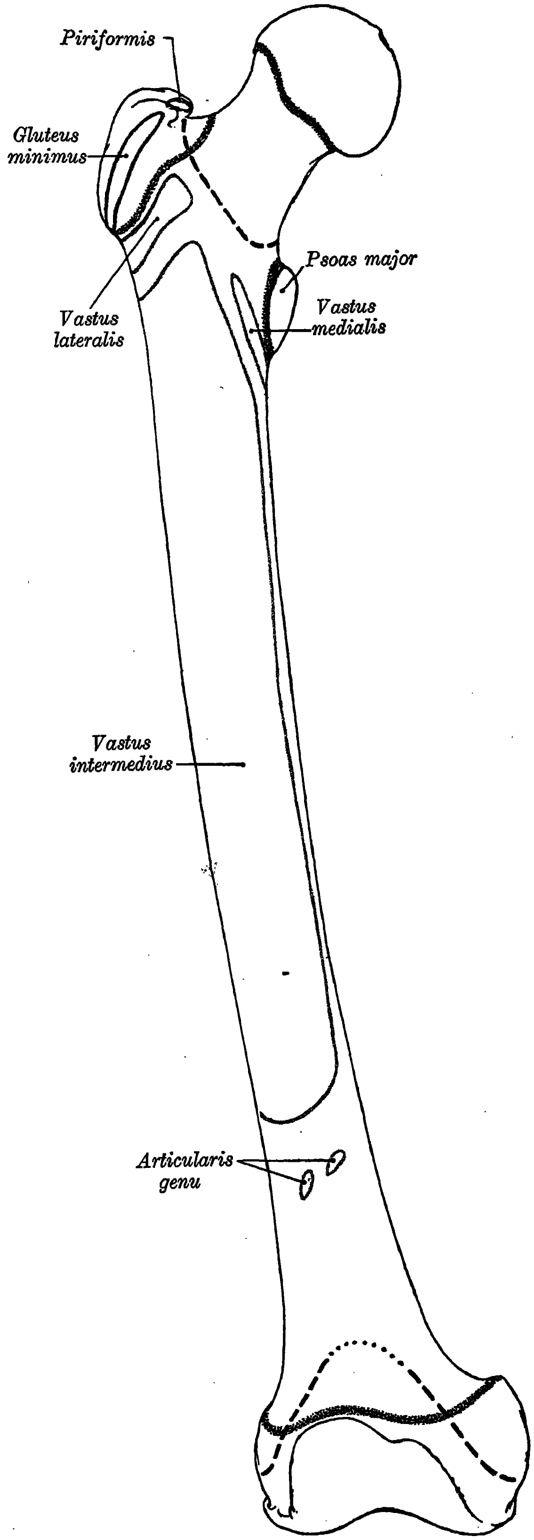
The *trochanteric line* marks the lateral limit of the capsular ligament of the hip-joint. Its upper part, including the tubercle already noticed (p. 385), receives the attachment of the upper band of the iliofemoral ligament; its lower part receives the lower band of the same ligament. The highest fibres of the vastus lateralis arise from the upper end of the line, and the highest fibres of the vastus medialis from its lower end.

The *trochanteric crest*, above the *quadrate tubercle*, is covered by the gluteus maximus muscle; below the tubercle it is separated from that muscle by the quadratus femoris and the upper border of the adductor magnus. The tubercle itself, and a portion of the bone below, receive the insertion of the quadratus femoris muscle.

The **shaft** of the femur (figs. 453 and 455) is thinnest at its middle: it expands a little as it is traced upwards, but it widens appreciably near the lower end of the bone.

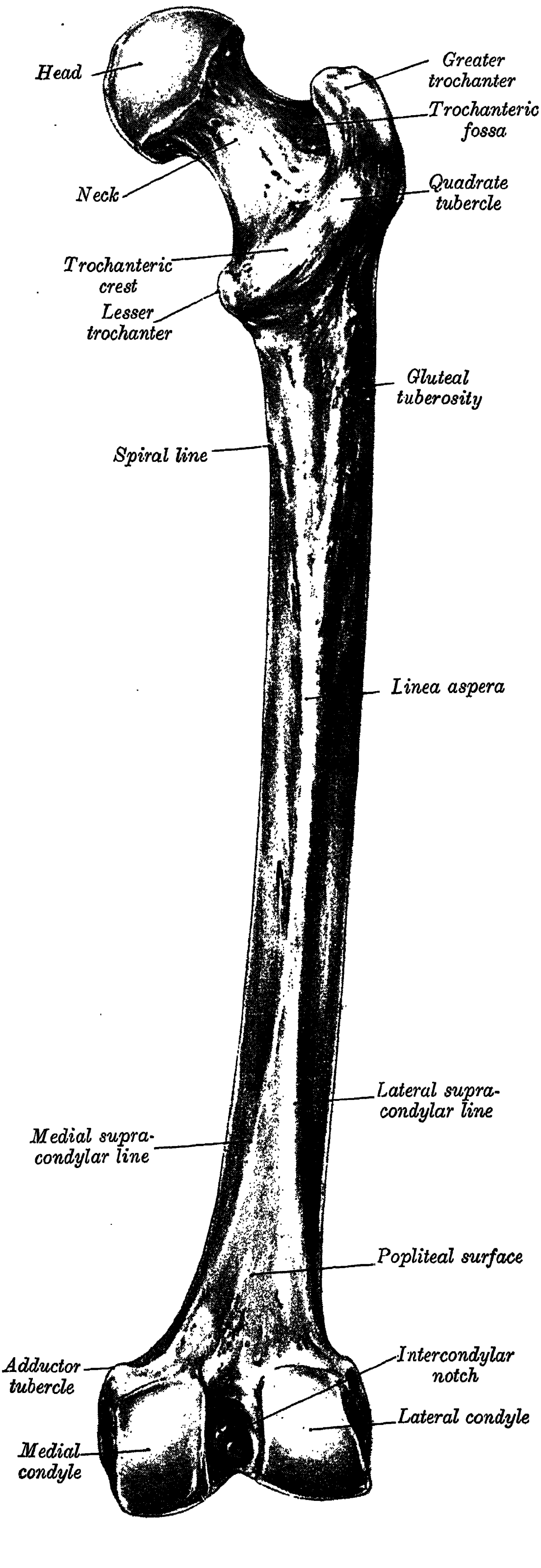
In its middle third the shaft possesses three surfaces and three borders. The *anterior surface*, which is smooth and gently convex in all directions, is easy to identify. It is placed between the lateral and the medial borders, which are both rounded and ill-defined. The *lateral surface* is directed more backwards than laterally, and is bounded in front by the lateral border and behind by the posterior border. The posterior border is formed by a broad, rough ridge, termed the **linea aspera**, which usually forms a crestlike projection, with distinct lateral and medial lips. In this situation the compact substance is increased in amount in order to compensate for the weakness caused by the curve of the bone. The *medial surface* is directed medially and slightly backwards; smooth,

FIG. 454.—Key to fig. 453.



The stippled lines mark the position of the epiphyseal lines. The interrupted lines correspond to the attachments of the capsular ligaments. The dotted part of the lower line indicates the site of communication between the cavity of the knee-joint and the suprapatellar synovial bursa.

FIG. 455.—The right femur. Posterior aspect.



like the two other surfaces, it is bounded in front by the medial border and behind by the linea aspera.

In its upper third the shaft presents a fourth surface, which is directed backwards. This *posterior surface* is bounded on the medial side by a narrow, roughened line termed the *spiral line*, which is continuous above with the lower end of the trochanteric line, and below with the medial lip of the linea aspera. On the lateral side the surface is bounded by a broad, roughened ridge termed the *gluteal tuberosity*, which extends upwards and laterally to the root of the greater trochanter and is continuous below with the lateral lip of the linea aspera. The posterior surface in this part of the bone is therefore V-shaped.

In its lower third also the shaft possesses a fourth, or *posterior surface*. This posterior surface is placed between the *medial* and *lateral supracondylar lines*, which are continuous above with the corresponding lips of the linea aspera. These two lines form definite but not conspicuous ridges, and of the two the lateral is the more distinct. Near its upper end the medial supracondylar line is in part obliterated; it is in this situation that the principal artery of the limb lies in close relation with the bone as it passes from the thigh to the popliteal fossa. The posterior surface of the lower third forms a flattened, triangular area, which is termed the *popliteal surface* of the femur (fig. 455); in its lower and medial part it presents a rough and slightly elevated area.

Particular features.—The shaft (figs. 454 and 456) is thickly covered with muscles and cannot be felt satisfactorily through the skin. Its *anterior* and *lateral surfaces* give origin in their upper three-fourths to the vastus intermedius; below that muscle the

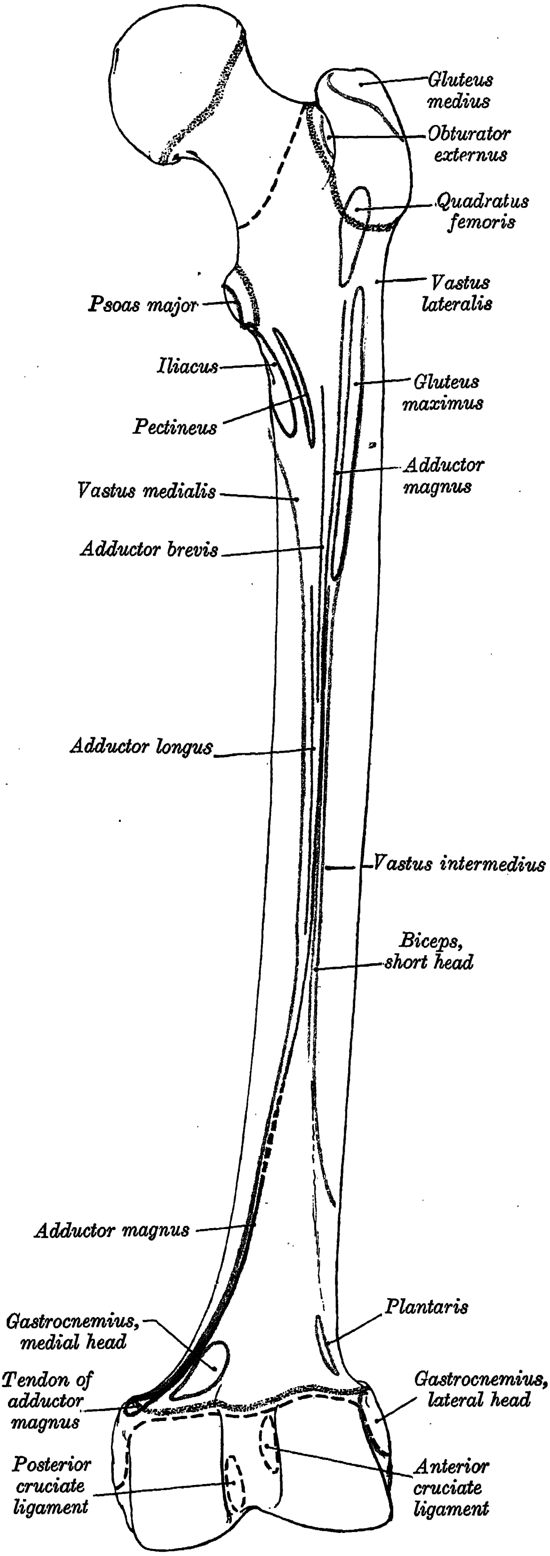
articularis genu arises by several small slips from the front of the bone. The lower portion of the anterior surface for 5 or 6 cm. above the patellar articular surface is covered by the suprapatellar bursa, which intervenes between the bone and the muscles mentioned. The lower portion of the lateral surface is covered by the vastus intermedius. The *medial surface* is devoid of muscular attachments and is covered by the vastus medialis.

The vastus lateralis has a linear origin which commences in front at the root of the greater trochanter and follows it to the upper end of the gluteal tuberosity. It then descends along the lateral margin of the tuberosity to the lateral lip of the linea aspera, from the upper half of which it takes origin. The vastus medialis also has a linear origin. It commences at the lower end of the trochanteric line and follows the spiral line to the medial lip of the linea aspera. At the lower end of the linea aspera it follows the medial supracondylar line in its upper half.

The *gluteal tuberosity* may take the form of an elongated, roughened depression or it may project as a salient ridge. Occasionally a part of it is sufficiently prominent to merit the name of a *third trochanter*. It receives the insertion of the deeper fibres of the lower half of the gluteus maximus muscle. The medial edge of the tuberosity provides insertion for the pubic fibres of the adductor magnus; the succeeding fibres of that muscle are inserted into the linea aspera and the upper part of the medial supracondylar line; the remaining fibres form a stout tendon which is inserted into the adductor tubercle (*vide infra*) and sends a membranous expansion to the lower part of the medial supracondylar line.

Between the gluteal tuberosity and the spiral line the posterior surface receives the insertions of the pectineus and the adductor brevis muscles. The pectineus is inserted into a line, sometimes slightly roughened, which descends from the root of the lesser trochanter to the upper end of the linea aspera. The adductor brevis is inserted lateral to the pectineus and ex-

Fig. 456.—Key to fig. 455.



The stippled lines mark the positions of the epiphyseal lines; the interrupted lines indicate the attachments of the capsular ligaments.

tends downwards to the upper part of the linea aspera, where it is attached medial to the adductor magnus.

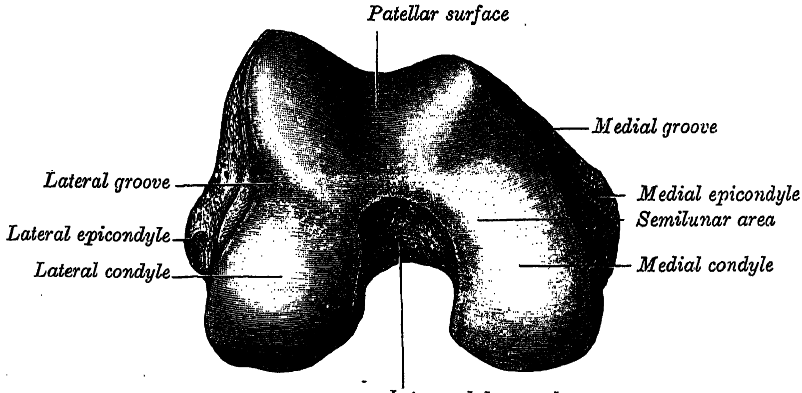
In addition to the attachments already described, the **linea aspera** receives the insertion of the adductor longus and the attachment of the lateral intermuscular septum, and gives origin to the short head of biceps femoris. The structures attached to the linea aspera may now be enumerated. From the lateral to the medial side they are: vastus lateralis, lateral intermuscular septum, short head of biceps femoris, adductor magnus, adductor brevis (to upper part only), adductor longus and vastus medialis; but it should be noted that the tendinous fibres are inseparably blended at their bony attachments. The perforating arteries cross the linea aspera from the medial to the lateral side, under cover of tendinous arches in the adductor magnus and the short head of the biceps femoris. The foramina for the nutrient arteries are situated close to the linea aspera. They vary in number and position. One is usually placed near the upper end of the linea aspera, and a second, which is not always present, near its lower end. The foramina are directed upwards through the compact substance.

The **popliteal surface** of the femur forms the floor of the upper part of the popliteal fossa. It is covered by a variable amount of fat, which separates the popliteal artery from the bone. The superior medial genicular artery arises from the popliteal artery as it lies in the intercondylar notch. It arches medially above the medial condyle, but is separated from the bone by the medial head of the gastrocnemius, which takes origin from the rough elevation placed a little above the medial condyle. The superior lateral genicular artery arches upwards and laterally above the lateral condyle, but is separated from the bone by the plantaris muscle, which arises from a small roughened area on the lower part of the lateral supracondylar line.

The *lateral supracondylar line* is most distinct in its upper two-thirds, to which the short head of the biceps femoris and the lateral intermuscular septum are attached. Its lower part is marked by a small roughened area which gives origin to the plantaris and often encroaches on to the popliteal surface. The medial supracondylar line is feebly marked in its upper two-thirds, where it gives origin to the vastus medialis. Near its upper end it is crossed by the femoral vessels as they enter the fossa from the subsartorial (adductor) canal. It is often sharp and prominent for 3 or 4 cm. above the adductor tubercle, and in this situation it gives attachment to a membranous expansion from the tendon of the adductor magnus muscle.

The **lower end** of the femur is widely expanded in order to provide a good bearing surface for the transmission of the weight of the body to the top of the tibia. It consists of two prominent masses of bone, termed the *condyles*, which are partially covered by a large *articular surface*. Anteriorly the two condyles are united and are in line with the front of the shaft; posteriorly they are separated by a deep notch, termed the *intercondylar notch*, and they project backwards considerably beyond the plane of the popliteal surface.

FIG. 457.—The lower end of the right femur. Inferior aspect.



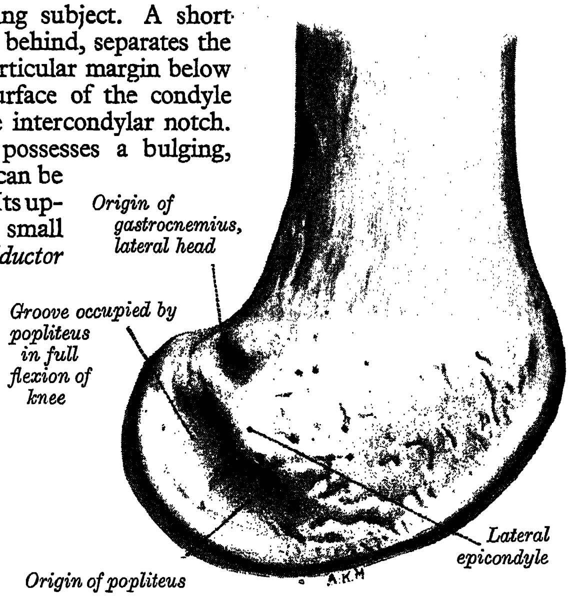
The *articular surface* forms a broad Λ-shaped area for articulation with the patella, or knee-cap, above and the tibia below (fig. 457). The *patellar surface* extends over the anterior surfaces of both condyles, but much the larger part of it is on the lateral condyle. It is concave from side to side, being grooved in its long axis to accommodate the posterior surface of the patella. The *tibial surface* is divided into medial and lateral parts by the intercondylar notch, but anteriorly

each part is directly continuous with the patellar surface. The medial part forms a broad strip which covers the convex inferior and posterior surfaces of the medial condyle, and is gently curved with the convexity of the curve directed medially. The lateral tibial surface covers the same aspects of the lateral condyle but forms a rather broader strip, which passes straight backwards.

The **lateral condyle** (fig. 458) is flattened on its lateral surface and is not so prominent as the medial condyle, but it is stouter and stronger, for it is placed more directly in line with the shaft and probably takes a greater share in the transmission of the weight to the tibia. The most prominent point on its lateral aspect is termed the *lateral epicondyle*, and the whole of this surface can be felt through the skin in the living subject. A short groove deeper in front than behind, separates the lateral epicondyle from the articular margin below and behind. The medial surface of the condyle forms the lateral wall of the intercondylar notch.

The **medial condyle** possesses a bulging, convex medial aspect, which can be palpated without difficulty. Its uppermost part is marked by a small projection termed the *adductor tubercle* (fig. 453) because it gives insertion to the tendon of the adductor magnus muscle. The tubercle is an important bony landmark for the surgeon, and can be identified most readily when it is approached from above. The most prominent point on the medial surface of the condyle is below and a little in front of the adductor tubercle and is termed the *medial epicondyle*. The lateral surface of the condyle is roughened and forms the medial wall of the intercondylar notch.

Fig. 458.—The lower end of the right femur. Lateral aspect.



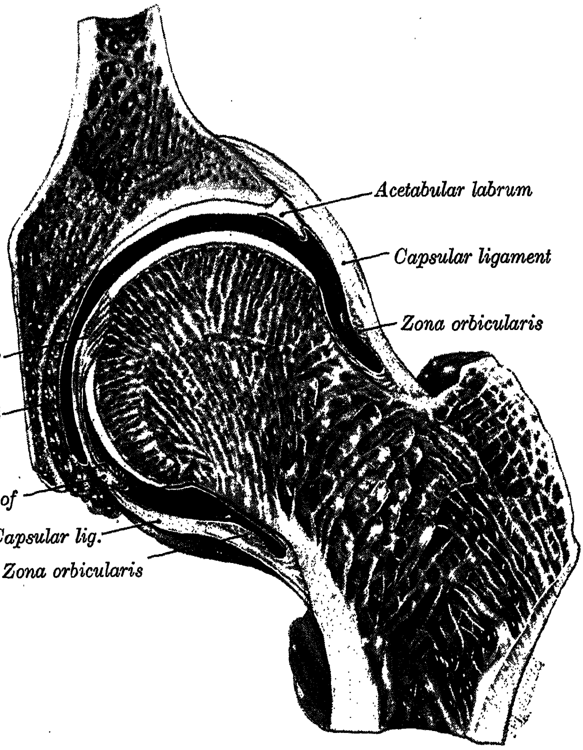
The **intercondylar notch** separates the two condyles below and behind. In front it is limited by the lower border of the patellar surface, and behind by the *intercondylar line*, which separates it from the popliteal surface. It lies within the capsular ligament of the knee-joint, but is covered with synovial membrane only over a very limited area.

Particular features.—The patellar surface extends higher on the lateral than on the medial side; its upper border therefore is oblique and runs downwards and medially (fig. 453). It is separated from the tibial surfaces by two faint grooves which cross the condyles obliquely. The lateral groove is the better marked (fig. 457); it runs laterally and slightly forwards from the front part of the intercondylar notch and expands to form a faint triangular depression, which rests on the anterior part of the periphery of the lateral semilunar cartilage (lateral meniscus), when the knee-joint is fully extended. The medial groove is restricted to the medial part of the medial condyle and rests on the anterior edge of the medial semilunar cartilage in the same position. Where this groove ceases the patellar surface is continued backwards on to the lateral part of the medial condyle as a semilunar area adjoining the anterior part of the intercondylar notch This area articulates with the medial vertical facet of the patella in forced flexion of the knee-joint; it is not distinctly outlined in most femora. The tibial surfaces are convex from side to side and from before backwards. The anteroposterior curvature of the two surfaces is not of the same degree throughout; the posterior part of each surface is the arc of a circle, but its anterior portion is part of a cycloid.* In full flexion of the knee-joint the sharply curved posterior parts of the tibial surfaces rest on the tibia and the semilunar cartilages (menisci), while their anterior parts are in contact with the infrapatellar pad of fat. In full extension the anterior parts rest on the tibia, while the posterior parts are in contact with the posterior part of the articular capsule.

* A cycloid is the curve traced by a point on the circumference of a wheel rolling along a straight line.

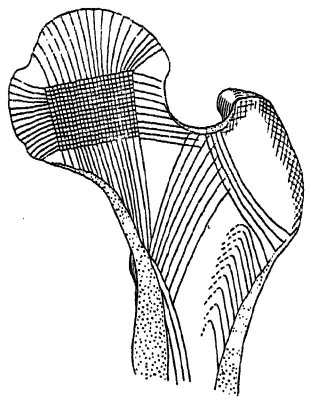
The medial condyle projects medially and downwards to such an extent that, despite the obliquity of the shaft, the lower surface of the lower end of the bone is practically horizontal. A curved strip, about 1 cm. wide, adjoining the medial margin of the articular

Fig. 459.—A section through the hip-joint. Compare with fig. 460 as regards the bone trabeculæ.



surface, is covered with synovial membrane and lies within the capsule of the knee-joint. The medial epicondyle, which lies above this area, gives attachment to the medial (tibial collateral) ligament of the knee-joint. In front of the epicondyle the medial condyle is related to the medial patellar retinaculum (tendinous expansion of vastus medialis).

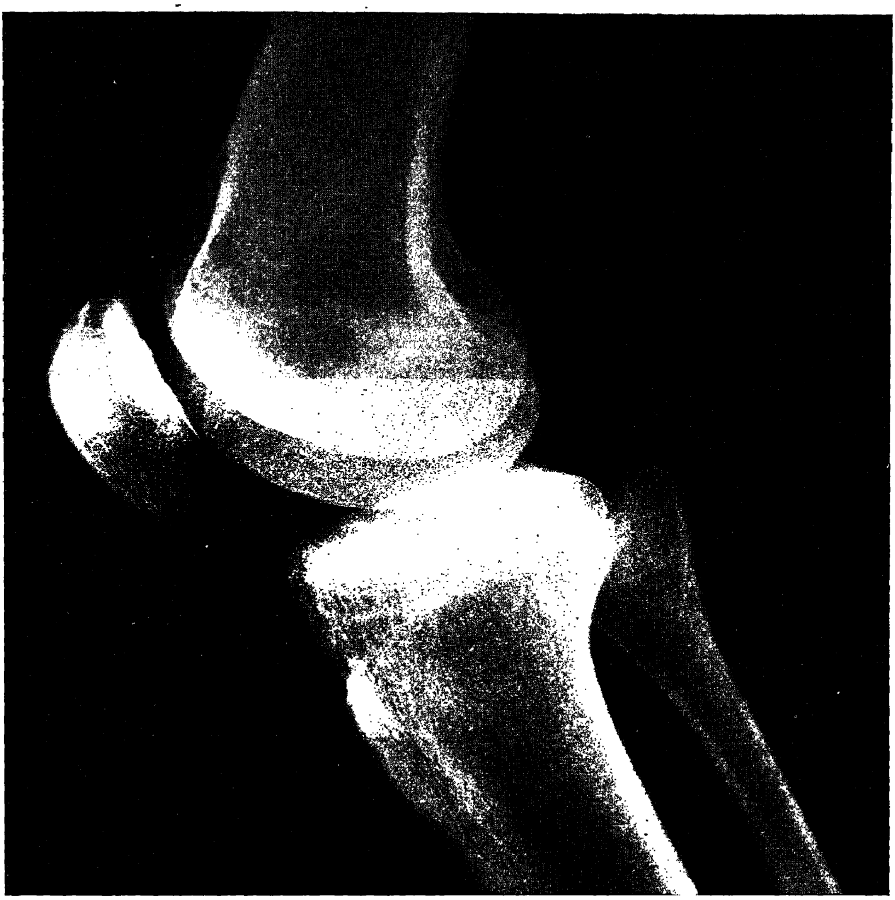
Fig. 460.—A scheme showing the disposition of the principal cancellous lamellæ in the upper end of the femur.



The **lateral condyle** is less prominent and its lateral surface projects but little beyond the lateral surface of the shaft. The lateral epicondyle gives attachment to the lateral (fibular collateral) ligament of the knee-joint, and above and behind it the bone bears an impression which gives origin to these fibres of the lateral head of the gastrocnemius that do not arise from the capsular ligament. The deepened, anterior end of the groove which lies between the epicondyle and the articular margin gives origin to the popliteus (fig. 458) muscle; the posterior or upper end of the groove lodges the tendon of the muscle only in full flexion of the knee. In extension the tendon passes across the margin of the articular surface below, and sometimes grooves it. Immediately adjoining the articular margin a strip of the lateral condyle, 1 cm. broad, is intracapsular, and is covered with synovial membrane, with the exception of the depression from which the popliteus arises.

The **intercondylar notch** separates the projecting portions of the two condyles, and is intracapsular but, to a large extent, extrasynovial. Its lateral wall, formed by the medial surface of the lateral condyle, bears a flattened impression which occupies its upper and posterior part and extends on to the floor of the notch close to the intercondylar line. This impression gives attachment to the upper end of the anterior cruciate ligament. The medial wall of the notch, formed by the lateral surface of the medial condyle, bears a similar but rather larger impression

PLATE IX



Radiograph of the knee region of an adult. Lateral view.

FIG. 1.—Radiograph of an adult knee. The gap between the lateral condyles of the femur and tibia is occupied by the articular cartilage of the two bones and the lateral semilunar cartilage.

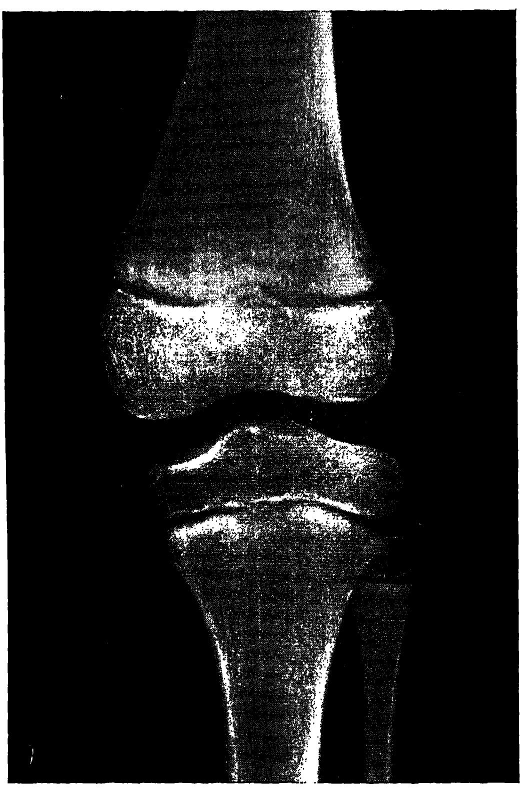
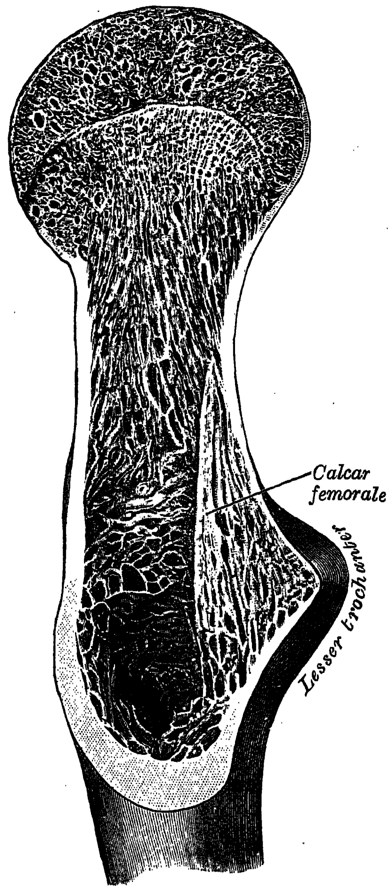


FIG. 2.—Radiograph of the knee of a child aged 7½ years. Note that the styloid process of the head of the fibula and the tubercles of the intercondylar eminence of the tibia are still cartilaginous and therefore cannot be recognised.

for the attachment of the upper end of the posterior cruciate ligament; it is placed anteriorly and extends on to the anterior part of the floor of the notch. These two impressions are relatively smooth, but the rest of the notch is rough and pitted by vascular foramina, although occasionally the bursal recess between the two ligaments extends upwards to reach it. The *intercondylar line* gives attachment to the capsular ligament and, laterally, to the oblique posterior (oblique popliteal) ligament of the knee-joint. The anterior border of the notch receives the upper attachment of the infrapatellar synovial fold.

Structure.—The shaft of the femur is a cylinder of compact bone, hollowed by a large medullary cavity. The wall of the cylinder is thick in the middle one-third of the shaft, where the bone is narrowest and the medullary cavity best formed; but above and below this the wall becomes thinner, while the medullary cavity is gradually filled up with spongy substance, so that the upper and lower ends of the shaft—and the articular extremities more especially—consist of spongy substance, invested by a thin compact layer.

Fig. 461.—An oblique section through the upper end of the left femur showing the calcar femorale.



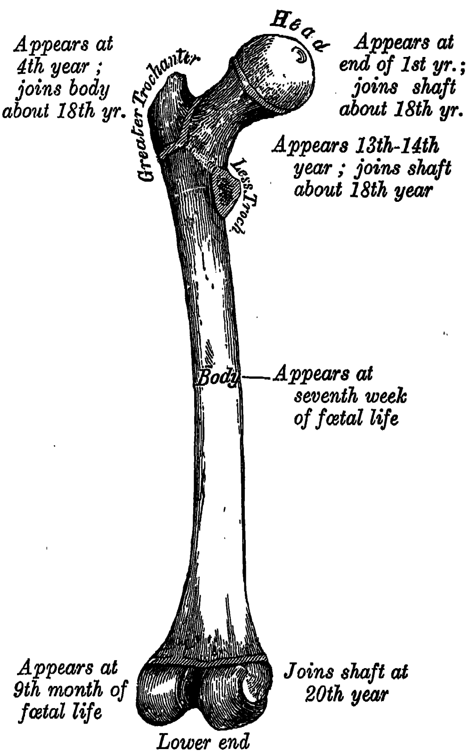
The trabeculæ in the ends of the femur are disposed along the lines of greatest pressure and tension. In the upper end (figs. 459, 460) the chief lamellæ are arranged in the following manner. A series of bony plates at right angles to the articular surface of the head converge to a central dense wedge; this wedge is supported by strong lamellæ which extend to the sides of the neck and are specially marked along its upper and lower borders. Any force therefore applied to the head of the femur is transmitted directly to the central wedge and thence to the junction of the neck with the shaft. This junction is in turn strengthened by a series of dense lamellæ which extend from the lesser trochanter to the lateral end of the superior border of the neck; this arrangement will obviously oppose considerable resistance to either tensile or shearing force. A smaller bar stretching across the junction of the greater trochanter with the neck and shaft resists the shearing force of the muscles attached to this prominence. These two bars—one at the junction of shaft and neck, the other at the junction of shaft and greater trochanter—form the upper layers of a series of arches which extend across between the sides of the shaft and transmit to it forces applied to the upper end of the bone. A thin vertical plate of bone, named the *calcar femorale* (fig. 461), springs from the compact wall of the shaft in the region of the linea aspera and extends into the spongy substance of the neck. Medially, it is attached to the inner surface of the posterior wall of the neck of the bone; laterally, it continues the plane of the posterior wall of the neck into the greater trochanter, where it shades off into the general spongy substance. It is thus situated in a plane anterior to the trochanteric crest and to the base of the lesser trochanter.

In the lower end, the trabeculæ spring on all sides from the inner surface of the cylinder, and descend in a direction perpendicular to the articular surface—the trabeculæ above the condyles being the strongest and having a more accurately perpendicular course. In addition to this, there are horizontal planes of

spongy substance, which in this situation is divided into a series of cubical compartments.

Ossification (figs. 454, 456, 462).—The femur is ossified from five centres: one each for the shaft, head, greater trochanter, lesser trochanter, and lower end. Except the clavicle, it is the first of the long bones to show traces of ossification. Ossification begins in the middle of the shaft in the seventh week of intrauterine life, and extends upwards and downwards. The secondary centres appear as follows: in the lower end, during the ninth month of intrauterine life (from this centre the condyles and epicondyles are formed); in the head at the end of the first year; in the greater trochanter during the fourth year; and in the lesser trochanter between the thirteenth and fourteenth years. The epiphyses, derived from the secondary centres, fuse independently with the shaft after puberty; the lesser trochanter joins first, then the greater, then the head, and, lastly, the lower end, which is not united until the twentieth year. It should be noted that the lower epiphyseal plate passes through the adductor tubercle (fig. 454).

FIG. 462.—A plan of the ossification of the femur. From five centres.



Applied Anatomy.—The lower end of the femur is usually the only epiphysis in which ossification has commenced at the time of birth. The presence of this centre of ossification is, therefore, a proof, in a new-born child found dead, that the child was viable, and is always relied upon in medico-legal investigations. The position of the epiphyseal plate should be carefully noted. It is on a level with the adductor tubercle, and the epiphysis does not, therefore, form the whole of the synovial covered portion of the lower end of the bone. It is essential to bear this point in mind when operations are performed on the lower end of the femur, since growth in length of the bone takes place chiefly from the lower epiphyseal cartilage, and any interference with it in a young child would involve such ultimate shortening of the limb, from want of growth, as to make the limb almost useless. Separation of the lower epiphysis may take place up to the age of twenty; but, as a matter of fact, few cases occur after the age of sixteen or seventeen. The epiphysis for the head is entirely intracapsular.

Fracture of the neck of the femur is usually termed *intracapsular* fracture, but this is not always a correct designation, as, owing to the attachment of the articular capsule, the fracture is partly within and partly without the capsule when the fracture occurs at the distal part of the neck. It generally takes place in old people, principally women, and usually from a very slight degree of indirect violence. Probably the main cause of its occurrence in old people is the senile degenerative change which takes place in the bone. Merkel believes that it is mainly due to the absorption of the calcar femorale. As a rule the fragments become united by fibrous tissue, but frequently no union takes place, and the opposed surfaces become smooth and eburnated.

Fractures at the junction of the neck with the greater trochanter are usually termed *extracapsular*, but this designation also is incorrect, for the fracture is partly within the capsule, as its attachment to the trochanteric line is beyond the line of fracture. These fractures are produced by direct violence to the greater trochanter, as from a fall laterally on the hip.

THE PATELLA

The **patella** (figs. 463, 464)*—the largest of the sesamoid bones—is situated in front of the knee-joint in the tendon of the quadriceps femoris. It is flattened and triangular, and has an anterior and a posterior surface, three borders, and an apex.

The *anterior surface* is convex, perforated by apertures for the passage of nutrient vessels, and marked by numerous rough, longitudinal striæ. It is separated from the skin by a bursa and is covered, in the recent state, by an expansion from the tendon of the quadriceps femoris; this expansion is continuous below with the superficial fibres of the ligamentum patellæ. The *posterior surface* presents in its upper part a smooth, oval, articular area, divided into two facets by a vertical ridge; the ridge corresponds to the groove on the patellar surface of the femur, and the facets to the medial and lateral parts of the same surface; the lateral facet is the broader and deeper. A narrow strip, broader above than below and often inconspicuous in the macerated specimen, is marked off from the medial part of the medial facet. This strip comes into contact with the medial condyle of the femur in extreme flexion of the knee-joint. Below the articular surface there is a rough, convex, non-articular area; its lower part gives attachment to the ligamentum patellæ; its upper part is covered by the infrapatellar pad of fat.

FIG. 463.—The left patella. Anterior aspect.

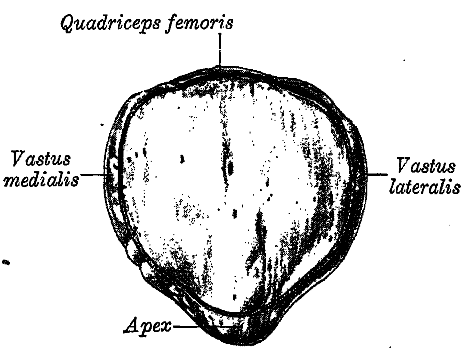
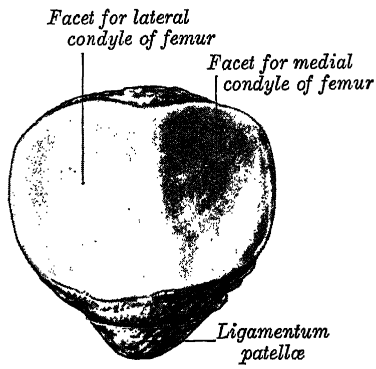


FIG. 464.—The left patella. Posterior aspect.



The *apex* is pointed, and gives attachment to the ligamentum patellæ.

The *base* or *superior border* is thick, and sloped from behind, downwards, and forwards: it gives attachment, except near its posterior margin, to that portion of the quadriceps femoris which is derived from the rectus femoris and vastus intermedius. The *medial* and *lateral borders* are thinner and they converge below: they give attachment to those portions of the quadriceps femoris which are derived from the vasti medialis et lateralis. Near the junction of the superior and lateral borders there is a small, shallow, circular depression into which a part of the tendon of the vastus lateralis is inserted.

Structure.—The patella consists of a nearly uniform dense spongy substance, covered by a thin compact lamina. The spaces immediately beneath the anterior surface are arranged parallel with it. In the rest of the bone they radiate from the articular surface towards the other parts of the bone.

Ossification.—The patella is ossified from a single centre which usually makes its appearance in the second or third year, but may be delayed until the sixth year. Ossification is completed about the age of puberty.

THE TIBIA (figs. 467–470)

General features.—The **tibia** is the medial and much the stronger of the two bones of the leg, and, excepting the femur, is the longest bone of the skeleton. It is prismoid in form, and possesses a shaft and two ends. Its *lower end* is smaller than

* The results of experimental excision of the patella in dogs are described by Eben J. Carey, Walter Zeit and Bernard F. McGrath, *American Journal of Anatomy*, vol. 40.

the upper end, and on its *medial side* a stout process, termed the medial malleolus, projects downwards beyond the rest of the bone. The *anterior border* of the shaft is a conspicuous, sharp crest, which curves medially at the lower end towards the medial malleolus; it is the most prominent of the three borders. The student should now be able to refer a given tibia correctly to its appropriate side.

The **upper end** of the tibia is expanded, especially in its transverse axis, to provide a good bearing surface for the body weight transmitted through the lower end of the femur. It comprises two prominent masses, named the *medial* and *lateral condyles*, and a smaller projection, termed the *tubercle of the tibia*. The condyles project backwards a little, so as to overhang the upper part of the posterior surface of the shaft, and superiorly each is covered by an articular surface, the two being separated by an irregularly roughened *intercondylar area*.

The **medial condyle** is the larger but does not overhang so much as the lateral condyle. Its upper articular surface (fig. 465), oval in outline, is concave in both diameters, and its lateral border projects upwards, deepening the concavity and covering an elevation, termed the medial intercondylar tubercle. The posterior surface of the condyle is marked, immediately below the articular margin, by a horizontal, roughened groove. Its medial and anterior surfaces form a rough strip, separated from the anterior surface of the shaft by an inconspicuous ridge.

Fig. 465.—The upper surface of the right tibia.

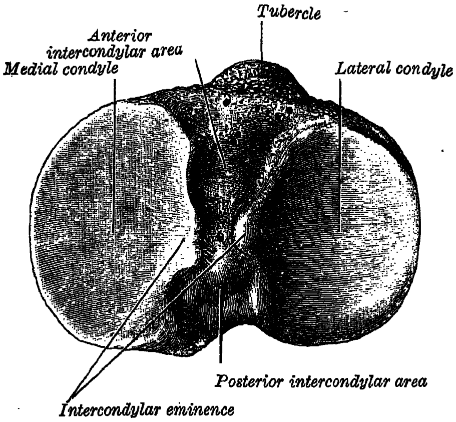
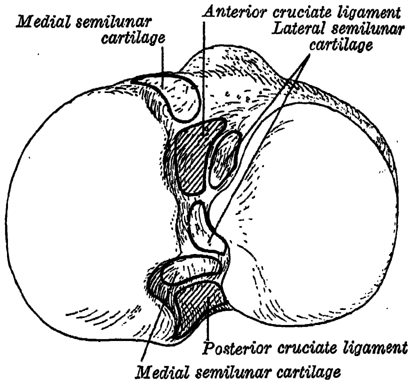


Fig. 466.—An outline of fig. 465 showing the attachments of the semilunar cartilages (menisci) and cruciate ligaments.



The **lateral condyle** overhangs the shaft, especially at its posterolateral part, which bears on its inferior surface a small circular facet for articulation with the upper end of the fibula. The upper surface (fig. 465) is covered with the articular surface for the lateral condyle of the femur. Nearly circular in outline, it is slightly hollowed in its central part, and its medial border extends upwards to cover an elevation, termed the lateral intercondylar tubercle. The posterior, lateral and anterior surfaces of the condyle are rough.

The anterior surfaces of the two condyles become continuous in front with a large triangular area, the apex of which is directed downwards and is formed by the tubercle of the tibia. The lateral edge of this area forms a sharp ridge which separates the lateral condyle from the lateral surface of the shaft.

The *intercondylar area* (fig. 465) is a roughened strip on the superior surface which intervenes between the articular surfaces of the two condyles. It is narrowest at its middle, where it is marked by an elevation termed the *intercondylar eminence*. The lateral and medial parts of the eminence project slightly upwards, and constitute the *lateral* and *medial intercondylar tubercles*. Both behind and in front of the eminence the intercondylar area becomes wider, as the curved margins of the articular surfaces recede from each other.

The **tubercle of the tibia** is placed at the upper end of the anterior border of the shaft, and is the truncated apex of the triangular area on the front of the bone where the anterior surfaces of the two condyles become continuous. It forms a low eminence, divided into a lower roughened and an upper smooth portion. The lower part can be felt through the skin, from which it is separated only by a bursa

termed the subcutaneous infrapateller bursa; the upper part gives attachment to the ligamentum patellæ.

Particular features.—The *articular surface of the medial condyle* is oval in shape, with its long axis anteroposterior. It is related around its anterior, medial and posterior margins to the medial semilunar cartilage (medial meniscus), and the area of contact is flattened. The imprint of the cartilage, which is widest behind and narrower at the medial side and in front, can often be recognised on the bone. The rest of the surface is concave, and its raised lateral margin covers the medial intercondylar tubercle. The *articular surface of the lateral condyle* is more nearly circular in shape. Like the medial articular surface it is related to the corresponding semilunar cartilage, and bears its flattened imprint. Elsewhere the surface is very slightly concave to adapt it to the surface of the corresponding femoral condyle, and its raised medial margin is continued on to the lateral aspect of the lateral intercondylar tubercle. The edges of the two articular surfaces are sharp except at the posterior part of the lateral surface, where the margin is smooth and rounded; in this situation the tendon of the popliteus is intimately related to the bone. The anterior and lateral margins of the lateral surface and the anterior, medial and posterior margins of the medial surface give attachment to the coronary ligaments (p. 498).

The *intercondylar area* (fig. 466) is widest anteriorly. In its anteromedial part, just in front of the medial articular surface, it bears a slight depression which gives attachment to the anterior horn of the medial semilunar cartilage. Behind that depression a relatively smooth area affords attachment to the lower end of the anterior cruciate ligament. The anterior horn of the lateral semilunar cartilage is attached to the bone in front of the intercondylar eminence and lies lateral to the anterior cruciate ligament. The *intercondylar eminence* occupies the narrow, middle part of the area, and is surmounted by two tubercles, of which the medial is slightly the more prominent. The posterior slope of the eminence gives attachment to the posterior horn of the lateral semilunar cartilage, and behind that the intercondylar area inclines downwards and backwards. A depression behind the base of the medial intercondylar tubercle gives attachment to the posterior horn of the medial semilunar cartilage. The rest of the area is smooth and affords attachment to the lower end of the posterior cruciate ligament, as far back as the ridge to which the capsular ligament is attached.

The groove on the posterior surface of the *medial condyle* receives the insertion of the semimembranosus muscle; its upper border receives the capsular ligament, and its lower border the posterior and shorter fibres of the medial ligament of the knee-joint. The medial and anterior surfaces of the condyle, which are marked by numerous vascular foramina, give attachment to the medial patellar retinaculum.

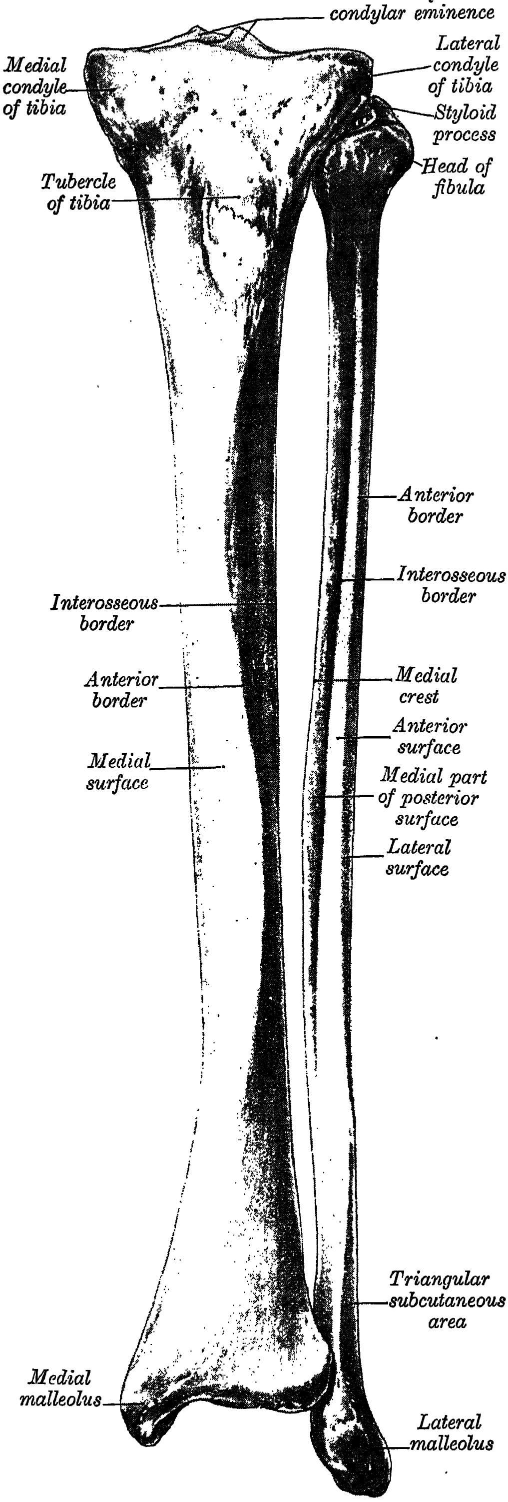
The *fibular facet* on the *lateral condyle* is directed downwards and slightly backwards and laterally. Above and to its medial side the posterior surface of the condyle is grooved by the tendon of the popliteus, but a bursa intervenes between the tendon and the bone. The lateral and anterior surfaces of the condyle are separated from the lateral surface of the shaft by a sharp margin which gives attachment to the deep fascia of the leg. An impression on the anterior surface, often well-marked though flattened, affords attachment for the iliotibial tract. Near the fibular facet the uppermost fibres of the extensor digitorum longus and peroneus longus arise from the lateral surface.

The tubercle of the tibia is subcutaneous in its lower part only; its upper part receives the attachment of the ligamentum patellæ. The two areas are sometimes separated by a rough crest, which receives the superficial fibres of the ligament. Above the tubercle the bone is related to the deep surface of the ligament, but the deep infrapatellar bursa and some fibro-fatty tissue intervene.

The shaft of the tibia (figs. 467, 469) is triangular on section, possessing medial, lateral and posterior surfaces, separated by anterior, interosseous and medial borders. It is thinnest at the junction of its middle and lower thirds, but expands considerably towards its upper and lower ends.

The *anterior border* commences at the tubercle of the tibia and runs downwards to the medial malleolus. It is subcutaneous throughout its whole length, and, except in its lower fourth, where it is rounded and indistinct, forms a sharp crest, which is familiarly known as the 'shin.' It is not straight, but follows a slightly sinuous course and its lower fourth diverges towards the medial side. The *interosseous border* commences below and a little in front of the fibular facet on the lateral condyle and descends to reach the anterior border of the fibular notch, which marks the lateral aspect of the lower end of the tibia. In nearly the whole of its length it affords attachment to the interosseous membrane which connects the tibia to the fibula. As a rule it is poorly defined at its upper end, but is easily identified in the rest of its extent. The *medial border* commences below the anterior end of the groove on the medial condyle and runs downwards to the posterior margin of the

FIG. 467.—The bones of the left leg. Viewed from in front.



medial malleolus. Its upper and lower fourths are rounded and ill-defined, but its middle third is sharper and can be recognised without difficulty.

The *medial surface* is bounded in front by the anterior border, and behind by the medial border. It is broad and smooth, and is subcutaneous throughout practically its whole extent. The *lateral surface*, also broad and smooth, is placed between the anterior and the interosseous borders. In its upper three-fourths it is directed laterally and is slightly concave from before backwards. Its lower fourth is carried round on to the front of the bone, owing to the deviation of the anterior border to the medial side and the forward inclination of the lower part of the interosseous border. This part of the surface is somewhat convex forwards. The *posterior surface* is bounded by the interosseous and the medial borders, and is widest at its upper end, where it is crossed from above downwards and medially by an oblique, roughened ridge, termed the *soleal line*. The area below this line is subdivided into medial and lateral parts by a faint *vertical line*, which begins at or just below the middle of the soleal line and soon fades away. A prominent vascular groove marks the bone near the upper end of the vertical line and descends to enter the large nutrient foramen; it may be situated either on the lateral or on the medial side of the vertical line.

Particular features.—The *anterior border* provides attachment for the deep fascia of the leg throughout its whole extent. A little above the medial malleolus it receives the medial end of the superior extensor retinaculum (transverse ligament of the leg). Above the soleal line the *medial border* gives attachment to the fascia covering the popliteus muscle and to the posterior fibres of the medial (tibial collateral) ligament of the knee-joint; below the soleal line it gives origin for a short distance to fibres of the soleus muscle and attachment to the fascia which covers the deep muscles of the leg. At its lower end it becomes continuous with the medial

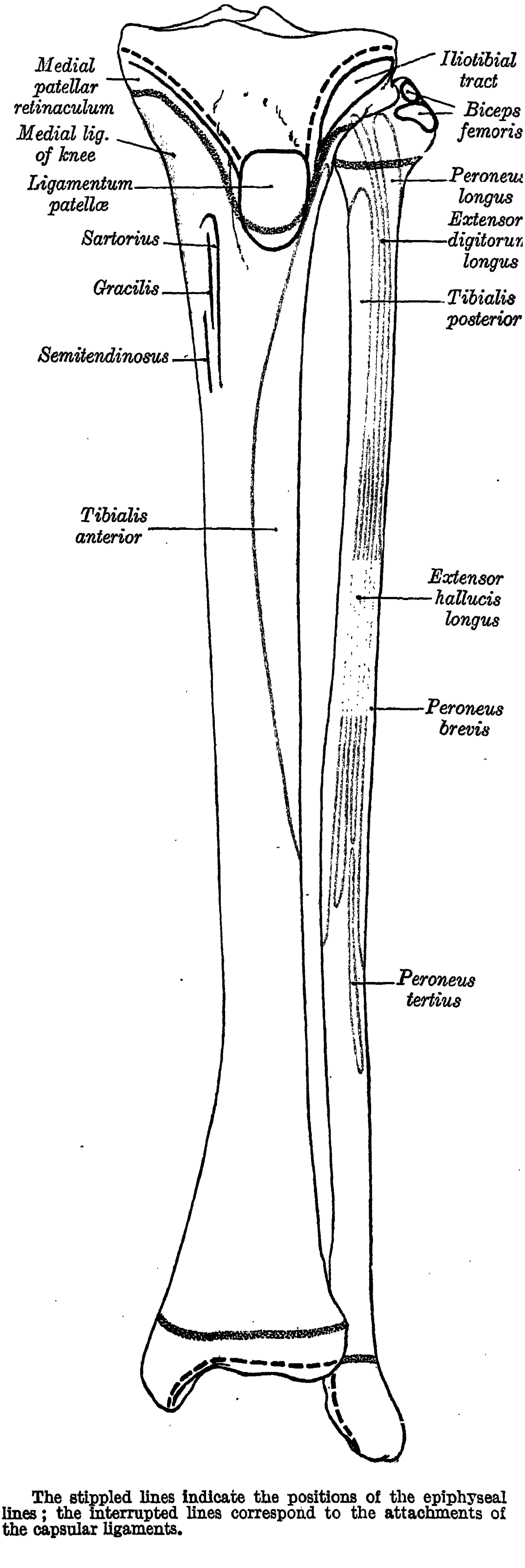
border of the groove which lodges the tendon of the tibialis posterior muscle. The *interosseous border* gives attachment to the interosseous membrane of the leg, except at its upper and lower ends. Its upper end is scarcely recognisable, and in this situation there is a large gap in the interosseous membrane for the passage of the anterior tibial vessels. Its lower end forms the anterior boundary of the fibular notch and gives attachment to the anterior inferior tibiofibular ligament.

The *medial surface* is usually roughened close to the upper part of the medial border over an area nearly 5 cm. long and 1 cm. wide; this area gives attachment to the longer fibres of the medial (tibial collateral) ligament of the knee-joint. In front of this roughened area the surface provides insertion for the tendons of the sartorius, gracilis and semitendinosus muscles, which however rarely produce markings on the bone. The gracilis, above, and the semitendinosus, below and behind, are inserted immediately in front of the ligamentous area; the sartorius is inserted into a line, which commences above and descends in front of the two other insertions (fig. 468). The rest of the surface is covered only by superficial fascia and skin, but its lower part is crossed obliquely by the long saphenous vein, as it ascends from in front of the medial malleolus.

The *lateral surface* gives origin in its upper two-thirds, or less, to the tibialis anterior muscle. Its lower part is devoid of muscular attachments, but is crossed by the tendon of the tibialis anterior (which lies along the lateral side of the anterior border), the extensor hallucis longus, the anterior tibial vessels and nerve (deep peroneal nerve), the extensor digitorum longus and peroneus tertius, in that order from the medial to the lateral side.

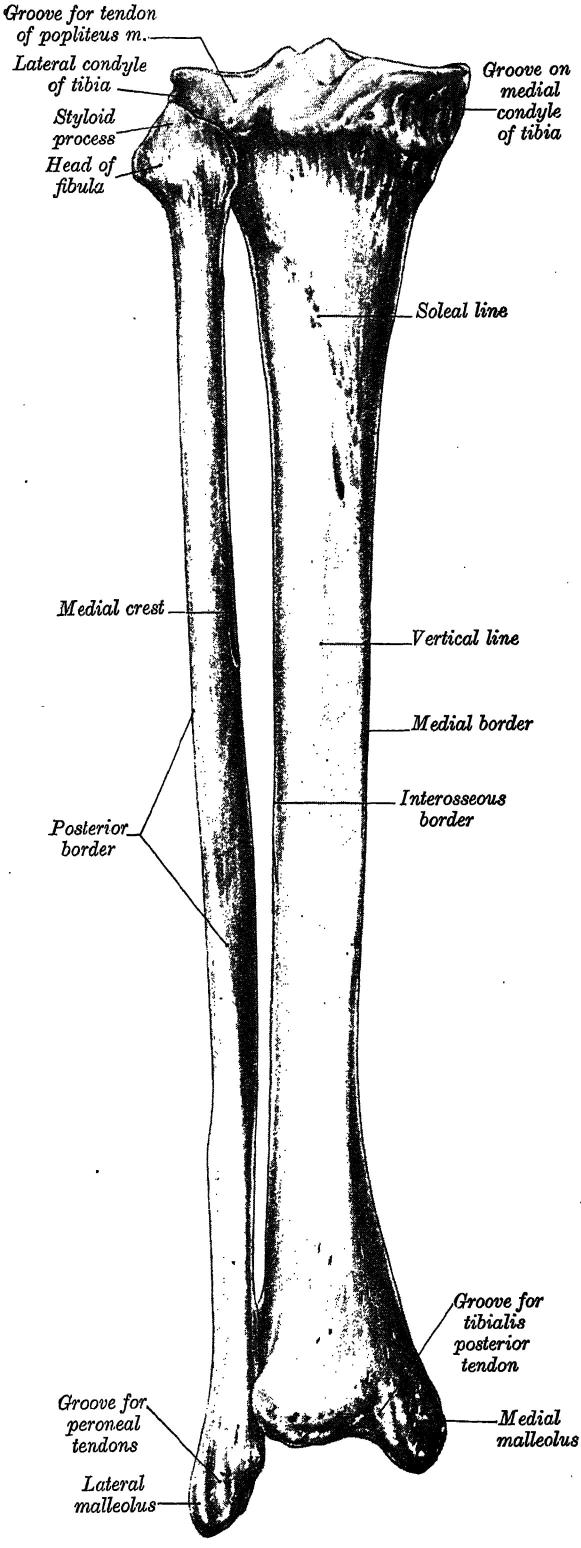
The *posterior surface* gives insertion to the popliteus over the triangular area above the soleal line, with the exception of the area adjoining the fibular facet. The *soleal line* gives attachment to the strong fascia which covers the popliteus muscle, and to the soleus muscle, its covering fascia, and the fascia covering the deep muscles of the leg. The upper end of the line does not reach the interosseous border and is marked by a tubercle, which gives attachment to the medial end of the tendinous arch in the soleus. Lateral to that tubercle the posterior tibial vessels and nerve descend on the

Fig. 468.—Key to fig. 467.



The stippled lines indicate the positions of the epiphyseal lines; the interrupted lines correspond to the attachments of the capsular ligaments.

FIG. 469.—The bones of the left leg. Viewed from behind.



surface of the tibialis posterior. Below the soleal line, the *vertical line* separates the origin of the flexor digitorum longus on the medial side from the origin of the tibialis posterior (fig. 470). The lower fourth, or more, of the posterior surface is devoid of muscular attachments, but is intimately related to the tendon of the tibialis posterior as it runs downwards and medially to reach the groove on the back of the medial malleolus. The flexor digitorum longus lies on the posterior surface of the tibialis posterior, crossing it obliquely from the medial to the lateral side, but the posterior tibial vessels and nerve and the flexor hallucis longus come into contact with the lateral part of this surface for a short distance above the lower end of the bone.

The lower end of the tibia is greatly expanded, and its medial portion projects downwards beyond the rest of the bone to form the medial malleolus. It possesses anterior, medial, posterior, lateral and inferior surfaces.

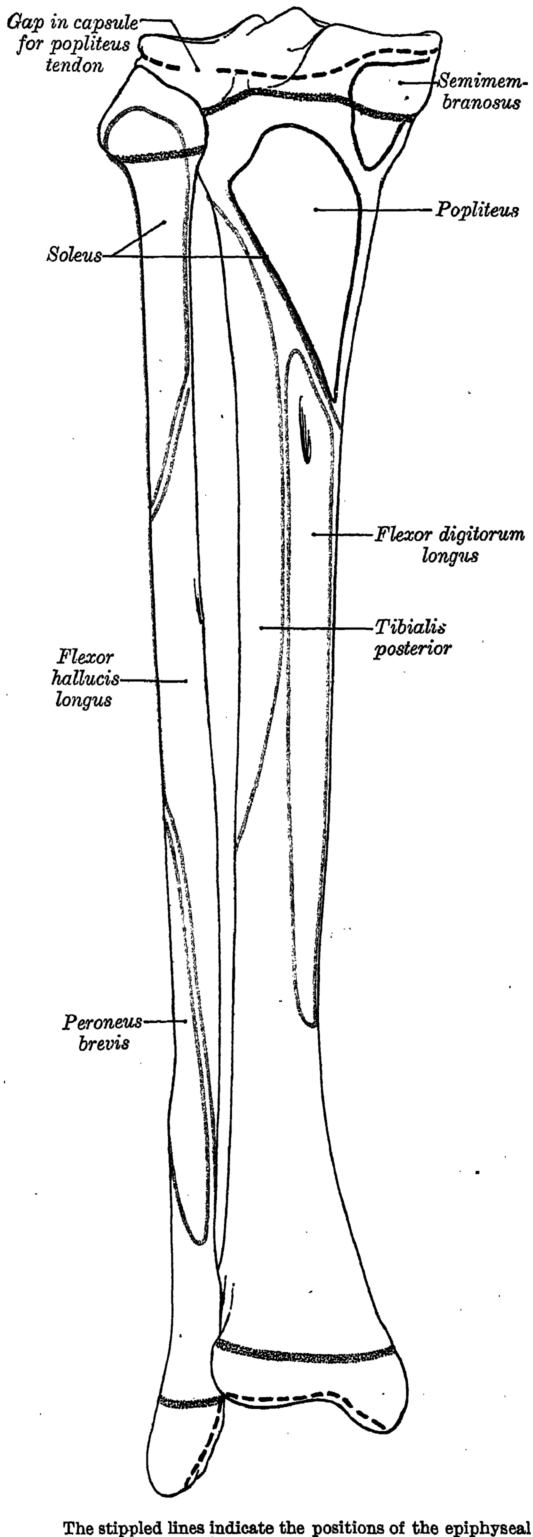
The *anterior surface* is smooth and bulges forwards beyond the inferior surface, from which it is separated by a narrow groove. It is continuous above with the lateral surface of the shaft. The medial surface also is smooth and is continuous above with the medial surface of the shaft and below with the medial surface of the medial malleolus. It is subcutaneous and can easily be felt through the skin. The *posterior surface* is crossed at its medial end by a groove which is usually conspicuous and can be traced down on to the posterior surface of the medial malleolus. Elsewhere this surface of the lower end is smooth and is continuous above with the posterior surface of the shaft. The *lateral surface* is formed by a triangular notch, termed the *fibular notch*, which is intimately related to the

lower end of the fibula. The anterior and posterior borders of the notch are salient and converge to meet above on the interosseous crest. The floor of the notch is roughened in its upper part for the attachment of the interosseous ligament which binds the lower ends of the two bones securely together. Its lower part is smooth and is sometimes covered with articular cartilage. The *inferior surface* is smooth for articulation with the body of the talus. Wider in front than behind, it is concave from before backwards and slightly convex from side to side. Medially it is uninterruptedly continuous with the articular surface of the medial malleolus.

The **medial malleolus** is a short but stout process. Its medial surface is smooth and convex, and can be felt easily through the skin. Its lateral surface is smooth and covered with a comma-shaped articular facet, which articulates with the medial side of the body of the talus. Its anterior surface is rough, and its posterior surface bears the lower end of the groove that marks the posterior surface of the lower end of the bone. The lower border of the malleolus is pointed in front, and behind that, it presents a depression for the attachment of the deltoid ligament of the ankle-joint.

Particular features.—The *anterior surface* of the lower end is related to the tendons, vessels and nerve which lie on the lower part of the lateral surface of the shaft and have already been enumerated (p. 399). The narrow groove adjoining the anterior border of the inferior surface gives attachment to the anterior ligament of the ankle-joint. The groove on the *posterior surface* lodges the tendon of the tibialis posterior, which at that level usually separates the flexor digitorum longus tendon from the bone. More medially the posterior tibial vessels and nerve and the flexor hallucis longus tendon are in contact with this surface. The floor of the *fibular notch*, especially in its rough upper part, gives attachment to the

FIG. 470.—Key to fig. 469.



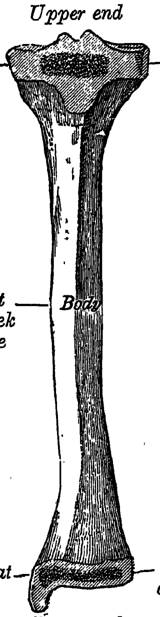
The stippled lines indicate the positions of the epiphyseal lines; the interrupted lines correspond to the attachments of the capsular ligaments

interosseous tibiofibular ligament; its lower smooth part may be covered with articular cartilage. The anterior and posterior borders of the notch give attachment respectively to the anterior and posterior inferior tibiofibular ligaments. The *medial malleolus* is shorter than the lateral malleolus, which lies on a more posterior plane. Its anterior surface gives attachment to the anterior and capsular ligaments of the ankle-joint. Its posterior surface is grooved by the tibialis posterior tendon, and the raised, medial margin of the groove gives attachment to the flexor retinaculum (laciniate ligament). The upper end of the deltoid ligament is attached to the lower border of the malleolus both to the pointed anterior part and to the depression behind it.

Structure.—The structure of the tibia is like that of the other long bones. The compact wall of the shaft is thickest at the junction of the middle with the lower one-third of the bone.

Ossification.—The tibia is ossified from three centres (figs. 468, 470, 471): one for the shaft and one for each end. Ossification begins in the middle of the shaft about the seventh week of intra-uterine life. The centre for the upper end appears before or shortly after birth, and from it a thin tongue-shaped process extends downwards in front to form the tubercle (fig. 471); the centre for the lower end appears in the second year. The lower end joins the shaft about the eighteenth year; the upper about the twentieth year. Two additional centres occasionally exist—one for the tongue-shaped process which forms the tubercle, and one for the medial malleolus.

FIG. 471.—A plan of the ossification of the tibia. From three centres.



THE FIBULA (figs. 467–470)

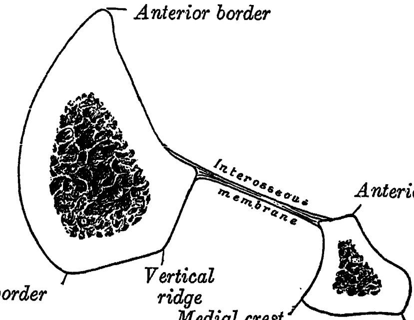
General features.—The **fibula** is the lateral bone of the leg, and is very slender as compared with the tibia, for it is not called upon to share in the transmission of the body weight. It possesses an upper end or head, a shaft and a lower end, which constitutes the lateral malleolus. The shaft shows considerable variation in its form, for it is moulded by the muscles to which it gives attachment; and these variations may prove confusing to the junior student. The *lower end* should be identified first. It is expanded antero-posteriorly but is flattened from side to side. It bears a triangular articular facet on the anterior part of its *medial surface*, which is directed medially to articulate with the talus. A well-marked depression, termed the malleolar fossa, lies *posterior* to the articular facet. The student has now been provided with sufficient information to enable him to determine the side to which a given fibula belongs.

The **head** of the fibula is slightly expanded in all its diameters, and projects beyond the shaft in front, behind and on the lateral side. It bears on its upper surface a nearly circular articular facet, which articulates with the inferior surface of the lateral condyle of the tibia; it is directed upwards, and slightly forwards and medially. A blunt elevation, termed the *styloid process*, projects upwards from the lateral part of its posterior surface. The head of the fibula can be felt through the skin on the posterolateral aspect of the knee, *nearly 2 cm. below the level of the knee-joint*. Immediately below the head a large nerve, termed the lateral popliteal nerve, crosses the posterolateral aspect of the constricted upper end of the shaft and can be rolled against the bone in the living subject. If sufficient pressure is exerted,

tingling sensations will be experienced on the dorsum of the foot, radiating to the toes, and especially to the medial side of the big toe.

The **lower end** or **lateral malleolus** projects downwards to a lower level than the tibia. Its lateral surface is subcutaneous and can be felt through the skin

FIG. 472.—A transverse section through the right tibia and fibula, showing the attachment of the crural interosseous membrane.



without difficulty; its posterior surface is marked by a broad groove with a prominent lateral border. Its anterior surface is rough and rounded and is continuous below with the inferior border. The medial surface (fig. 473) presents a triangular articular facet, with its apex pointing downwards, which articulates with the lateral surface of the talus in the ankle-joint; it is convex from above downwards. Behind the articular facet the bone is marked by a roughened depression, termed the *malleolar fossa*, which readily admits the tip of a finger.

FIG. 473.—The lower end of the right fibula. Medial aspect.

The **shaft** of the fibula (figs. 467, 469) possesses three borders and three surfaces, each of which can be associated with a particular group of muscles. The borders are anterior, posterior and interosseous, and they should be identified first. At its lower end the *anterior border* divides to enclose an elongated, triangular area which is continuous below with the lateral surface of the lateral malleolus. Traced upwards, it ascends to reach the anterior aspect of the head. The *posterior border* is continuous with the medial margin of the groove on the back of the lateral malleolus. Usually sharp and distinct in its lower part, it is often rounded in the upper half of its extent. The *interosseous border* lies to the medial side of the anterior border and as a rule is on a more posterior plane (fig. 472), but in the upper two-thirds of the bone these two borders are very close to each other, and the intervening surface may be 1 mm. or less in width.

The *lateral surface* is bounded by the anterior and posterior borders. It is associated with the peroneal muscles, and is directed laterally in its upper three-fourths. Its lower fourth inclines backwards and becomes continuous with the groove on the back of the lateral malleolus. The *anterior surface* is bounded by the anterior and the interosseous borders. It is usually directed forwards and medially, but frequently faces directly forwards. Wider below, it becomes

very narrow in its upper half, and may be reduced to little more than a rounded ridge on the upper part of the shaft. It is associated with the extensor muscles of the leg. The *posterior surface* is the largest of the three and is placed between the interosseous and the posterior borders. It is associated with the flexor muscles of the leg. In its upper two-thirds it is divided into two areas by a longitudinal ridge, termed the *medial crest*, which is separated from the interosseous border by a grooved surface, directed medially. The rest of the posterior surface faces backwards in its upper half or more, but its lower part curves round on to the medial aspect and is directed medially. The lower part of this area fits into the fibular notch on the tibia and is roughened for the attachment of the interosseous tibiofibular ligament.

The elongated, triangular area immediately above the lateral surface of the lateral malleolus is subcutaneous, but the rest of the shaft is covered with muscles and cannot be examined satisfactorily in the living subject.

Particular features.—The *head of the fibula* affords origin to fibres of the extensor digitorum longus in front, peroneus longus anterolaterally, and soleus behind. The tendon of biceps femoris gains its principal insertion into the anterolateral, sloping surface of the styloid process, but it is split near its insertion by the lower part of the lateral ligament of the knee-joint, and its smaller anterior part passes into the lateral aspect of the head, above the origin of the peroneus longus. A flattened impression on the lateral aspect of the head receives the lower attachment of the lateral ligament of the knee-joint. The margins of the articular facet provide attachment for the capsular ligament of the superior tibiofibular joint.

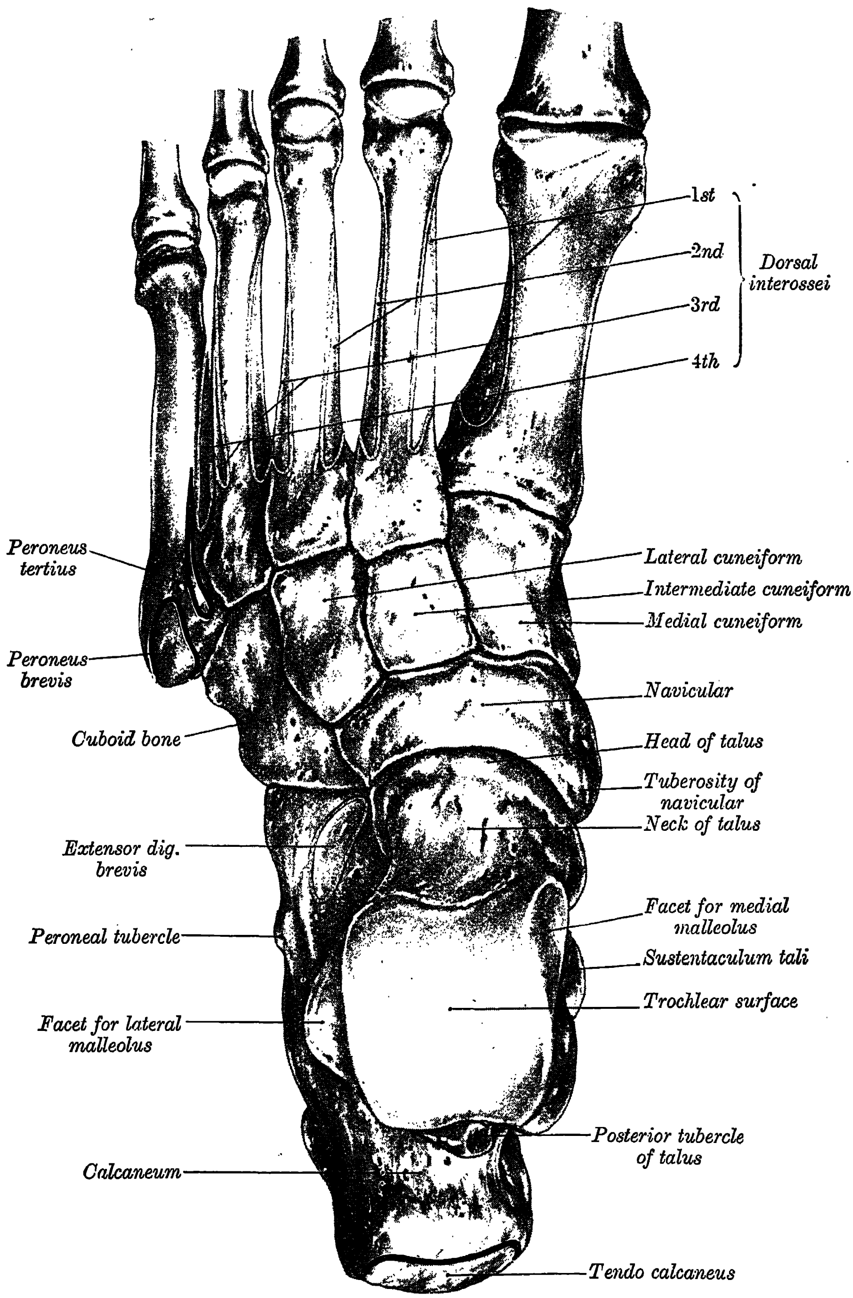
Fig. 474.—A plan of the ossification of the fibula. From three centres.

The *anterior border* of the fibula divides inferiorly into two ridges which enclose between them a subcutaneous triangular surface (fig. 473). The anterior intermuscular septum of the leg is attached to its upper three-fourths, and the lateral extremity of the superior extensor retinaculum (transverse ligament of the leg) to the lower part of the anterior border of the triangular area. The lower part of the posterior margin of the triangular area gives attachment to the lateral extremity of the superior peroneal retinaculum. The *interosseous border* terminates below at the upper extremity of the roughened area for the attachment of the tibiofibular interosseous ligament. It provides attachment for the interosseous membrane and does not reach so high as the head of the bone, on account of the gap in the upper part of the membrane for the transmission of the anterior tibial vessels. The *posterior border* is not always recognisable at its upper end; below, it becomes continuous with the medial border of the groove on the back of the lateral malleolus. Except at its lower end it gives attachment to the posterior intermuscular septum of the leg. The *medial crest* of the bone is intimately related to the peroneal artery, and the nutrient foramen of the fibula is situated either on the crest or in its immediate vicinity near the middle of the shaft. It gives attachment to a layer of the deep fascia of the leg which separates the tibialis posterior from the flexor hallucis longus and the flexor digitorum longus muscles.

The *anterior surface* of the fibula is often termed the *extensor surface*, for it gives origin to the extensor digitorum longus, the extensor hallucis longus and the peroneus tertius. The extensor digitorum longus arises from the whole breadth of the upper fourth of the surface and from the anterior part of the succeeding two-fourths; the extensor hallucis longus arises from its middle two-fourths behind the extensor digitorum longus; the peroneus tertius arises from its lower fourth or more, and is directly continuous with the lower part of the extensor digitorum longus. The *lateral surface* is frequently termed the *peroneal surface*, because it gives origin to the peroneus longus and the peroneus brevis. The peroneus longus arises from the whole extent of the upper third of the surface and from the posterior part of the middle third. The peroneus brevis arises in front of the lower half of the peroneus longus and extends downwards beyond it almost to the lower end of the bone. On account of the relative attachments of their fleshy bellies the tendon of the peroneus

brevis is closely applied to the bone below and separates it from the tendon of the peroneus longus. The *posterior surface*, which is divided longitudinally into two parts by the medial crest, is often termed the *flexor surface*. The portion which lies between the crest and the interosseous border is slightly hollowed out and gives origin to the tibialis posterior; it is

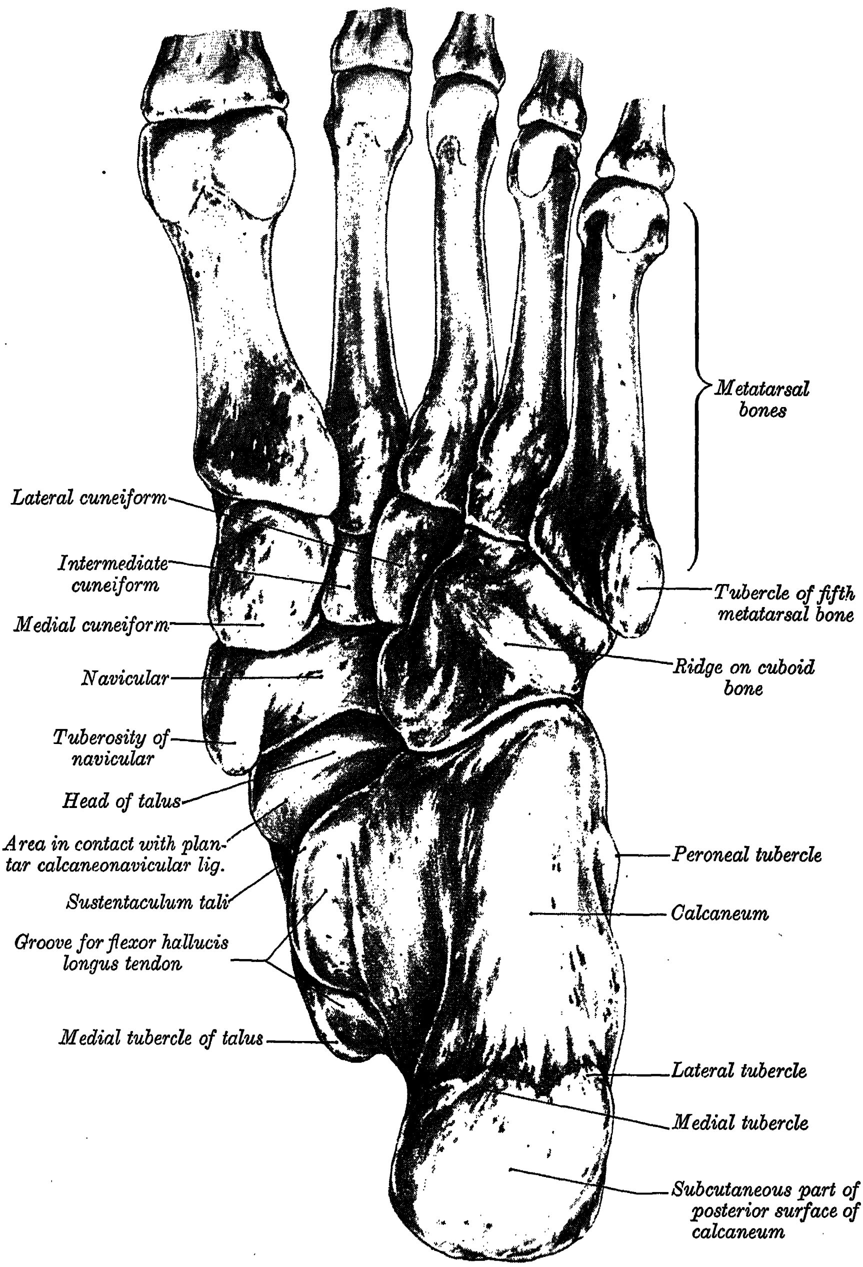
FIG. 475.—The tarsus and metatarsus of the left foot. Dorsal aspect.



often crossed by an oblique ridge which gives attachment to an intramuscular tendon. This part of the surface is usually confined to the upper three-fourths of the shaft, and at its lower end the medial crest becomes confluent with the interosseous border. The portion of the posterior surface which lies between the medial crest and the posterior border gives origin in its upper fourth to the soleus, which extends upwards on to the posterior aspect of the head; near the upper end of the medial part of this origin a roughened tubercle marks the lateral end of the tendinous arch which is thrown across the posterior tibial

vessels and nerve by the soleus muscle. Below the origin of the soleus the remainder of this surface gives origin to the flexor hallucis longus, whose origin extends downwards almost to the lower end of the bone. The triangular area of the shaft above the lateral malleolus is covered only by the superficial fascia and the skin. Above the lateral malleolus a triangular

FIG. 476.—The tarsus and metatarsus of the left foot. Plantar aspect.



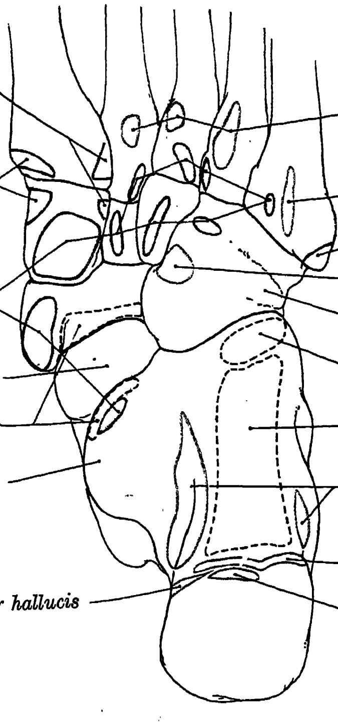
area on the medial surface of the shaft gives attachment to the interosseous tibiofibular ligament (fig. 473) and its anterior and posterior margins to the corresponding ligaments of the inferior tibiofibular joint.

The anterior surface of the *lateral malleolus* gives attachment to the anterior talofibular ligament. The lower border is marked in front by a slight notch and behind by a small projection which constitutes the apex of the malleolus. It is to the notch that the calcaneofibular ligament is attached. The groove on the posterior aspect lodges the tendons

of the peroneus brevis and peroneus longus ; the latter is the more superficial and is closely covered by the superior peroneal retinaculum. The *malleolar fossa* (fig. 473) is pitted by numerous small vascular foramina ; its upper part gives attachment to the inferior transverse tibiofibular ligament, its lower part to the posterior talofibular ligament.

Ossification.—The fibula is ossified from three centres (fig. 474) : one for the shaft, and one for each end. Ossification begins in the shaft about the eighth week of intrauterine life, in the lower end during the second year, and in the upper about the fourth year. The lower epiphysis—the first to ossify—unites with the shaft about the twentieth year ; the upper about the twenty-fifth year.

FIG. 477.—Key to fig. 476.



THE SKELETON OF THE FOOT

The skeleton of the foot has three segments : the tarsal bones, the metatarsal bones, and the phalanges or bones of the digits.

THE TARSUS (figs. 475–477)

The **tarsus** comprises seven short bones which make up the skeleton of the posterior half of the foot. It is homologous with the carpus but its constituent elements are larger and stronger, on account of the part they play in supporting and distributing the weight of the body in the erect attitude. Like the bones of the carpus the tarsal bones are arranged in a proximal and a distal row, but an additional element is interposed between the two rows on the medial side. The proximal row comprises the **talus** and the **calcaneum.** These two bones do not lie side by side ; the talus is placed above the calcaneum, but its long axis is directed forwards, medially and downwards, so that its anterior end or head comes to lie on the medial side of the calcaneum, though at a higher level. The distal row comprises four bones, named, from the medial to the lateral side, the **medial cuneiform,** the **intermediate cuneiform,** the **lateral cuneiform** and the **cuboid.**

These bones lie side by side and together contribute to the formation of a transverse arch, which is convex upwards. On the medial side the **navicular bone** is interposed between the talus and the medial three bones of the distal row. On the lateral side the calcaneum articulates directly with the cuboid bone.

Fig. 478.—The left talus. Superior aspect.

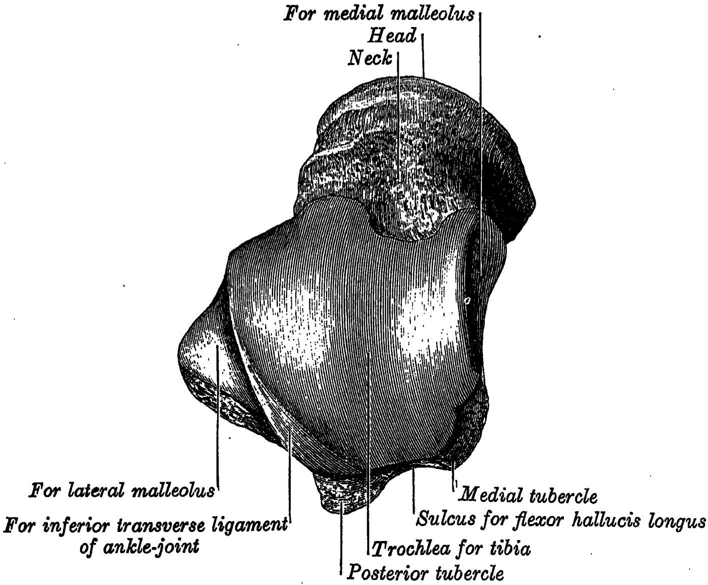
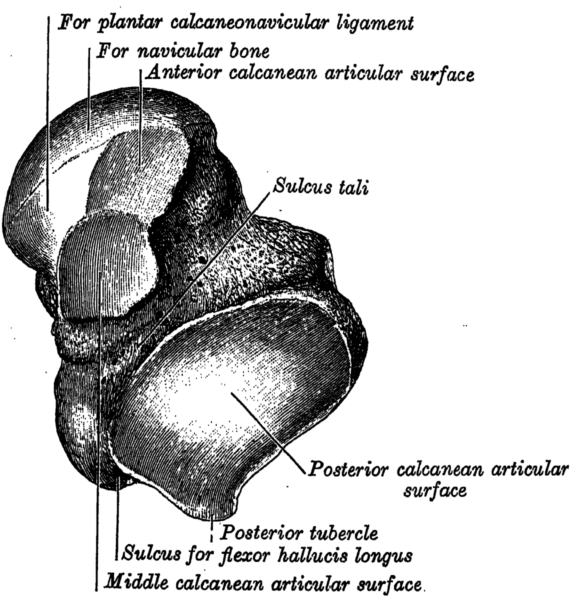


Fig. 479.—The left talus. Plantar aspect.



The foot is set at right angles to the leg, and the tarsus and metatarsus are arranged in such a way as to form intersecting longitudinal and transverse arches (fig. 497). As a result the weight is not transmitted to the ground from the tibia directly through the tarsus, but is distributed through the tarsal and metatarsal bones to the extremities of the arches (see p. 423). Each of the tarsal bones is roughly cuboidal in form and presents six surfaces for examination.

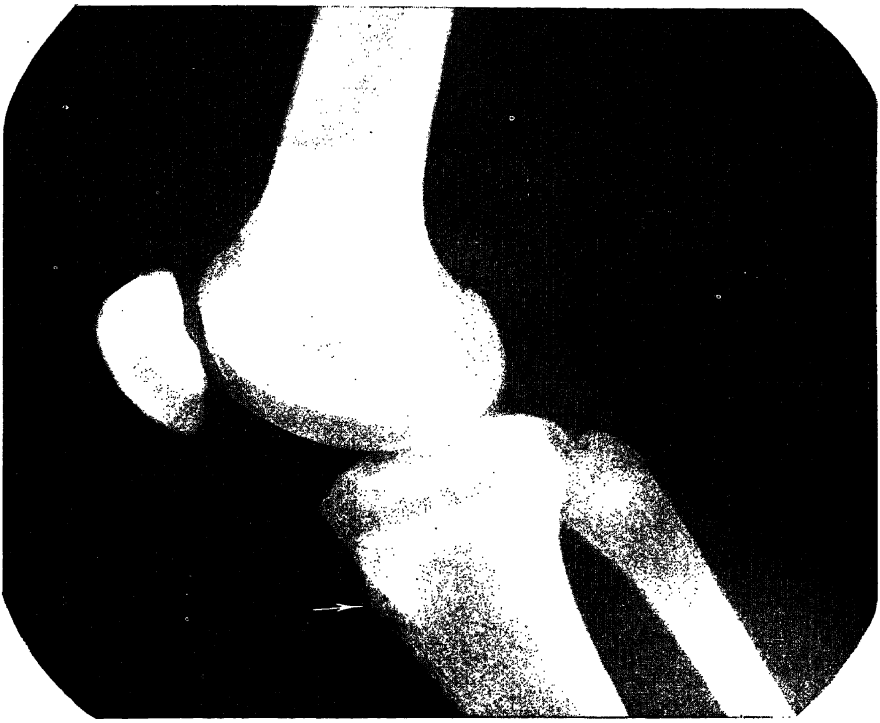


Fig. 1.—Radiograph of the knee of a boy aged 16 years. Lateral view. Note that the upper epiphysis of the tibia includes the tibial tubercle, which is indicated by the arrow.

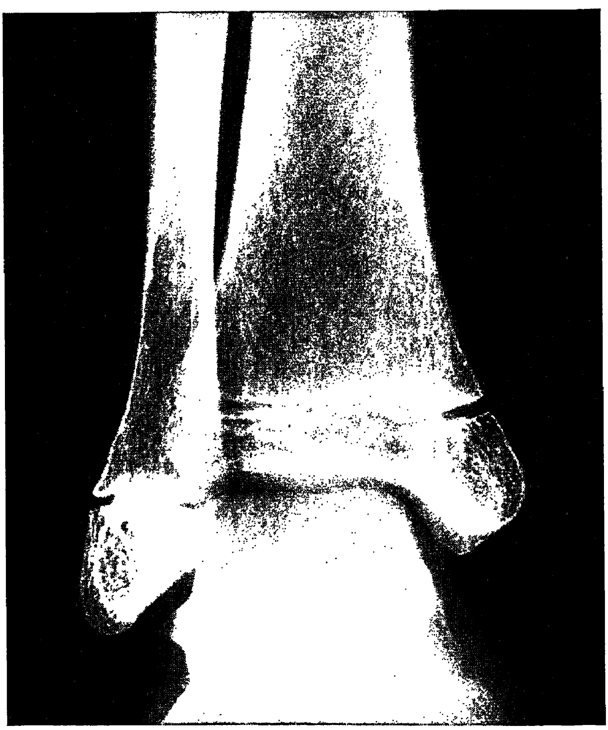
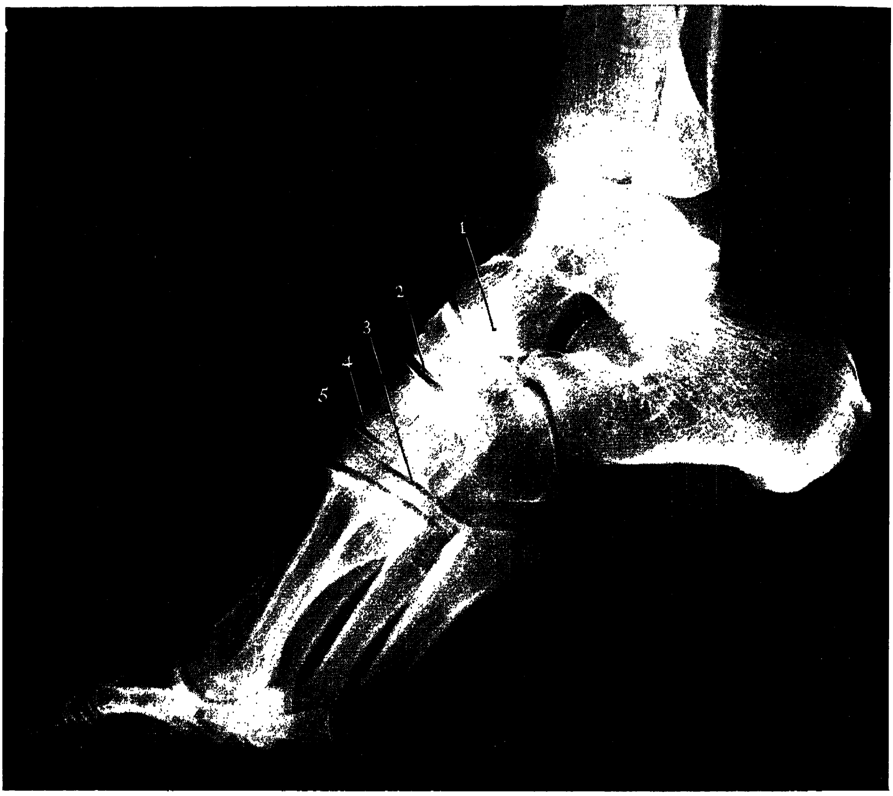


Fig. 2.—Radiograph of the ankle of a child aged 10 years. Note that the inferior epiphyseal line of the fibula is opposite the ankle joint.

PLATE XII



Radiograph of an adult foot. 1 = tuberosity of navicular bone, partly obscured by the shadow of the head of the talus. 2 = cuneo-navicular joint. 3 = joint between metatarsal III and the lateral cuneiform bone. 4 = joint between metatarsal II and the intermediate cuneiform bone. 5 = joint between metatarsal I and the medial cuneiform bone.

THE TALUS (figs. 478–481)

General features.—The **talus** is the principal connecting link between the foot and the bones of the leg, and takes an important part in the formation of the ankle-joint. The rounded head, which is placed at the *anterior* end of the bone, the trochlear surface for the tibia on the *superior* surface and the large triangular facet for the lateral malleolus on the *lateral* surface can be recognised without difficulty, and enable a talus to be referred to its appropriate side of the body.

The talus possesses a head, a neck and a body.

The **head** of the talus is directed forwards and slightly downwards and medially. Its *anterior surface*, which is oval and convex, with its long axis directed downwards and medially, articulates with the posterior surface of the navicular bone. The

FIG. 480.—The left talus. Medial aspect.

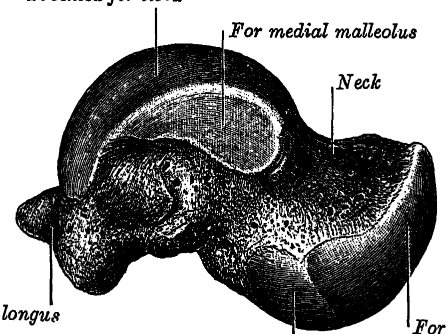
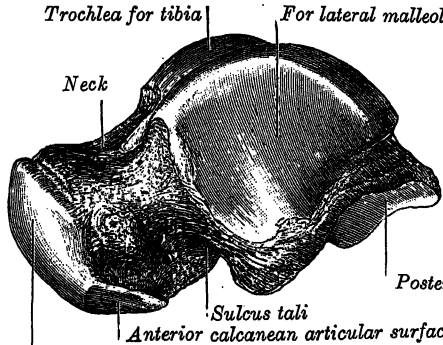


FIG. 481.—The left talus. Lateral aspect.



inferior surface is marked by three articular areas, which are separated by indistinct ridges. Of these areas the most posterior is the largest; oval in outline, it is gently convex and rests on the upper surface of a shelf-like projection from the medial side of the calcaneum named the sustentaculum tali. Anterior and lateral to this area, and usually continuous with it, a flattened articular facet rests on the anterolateral part of the upper surface of the calcaneum; it is continuous in front with the navicular surface. Medial to the two calcanean facets a part of the head of the talus is exposed on the plantar aspect of the articulated foot. This area is covered with articular cartilage and is continuous on the one hand with the calcanean areas and on the other with the navicular area. In the recent state it lies in contact with an important ligament named the *plantar calcaneonavicular* or '*spring*' *ligament* (p. 511).

The **neck** of the talus is the slightly constricted part which connects the head to the body. It is set very obliquely on the body and extends farther backwards

on the medial side than on the lateral side. Its roughened surfaces give attachment to ligaments, and the medial part of its inferior surface exhibits a deep groove, termed the *sulcus tali*. When the talus and calcaneum are articulated together this groove forms the roof of a bony canal, termed the *sinus tarsi*, which is occupied by the interosseous talocalcanean ligament.

The **body** of the talus is cuboidal in shape. Its superior surface is covered by a *trochlear* articular surface, which articulates with the lower end of the tibia in the ankle-joint. It is convex from before backwards and gently concave from side to side, and it is important to observe that it is widest anteriorly. The *lateral surface*, triangular in outline, is smooth for articulation with the lateral malleolus, and is concave from above downwards. Superiorly it is continuous with the trochlea; inferiorly its apex forms the *lateral tubercle* of the talus. The *medial surface* is covered in its upper part by a comma-shaped articular facet which is deeper in front than behind and articulates with the medial malleolus. Below the facet the surface is rough and is pitted by numerous vascular foramina. The *posterior surface* is rough, is small in extent and is marked by an oblique groove placed between two tubercles. The *posterior tubercle*, which is usually the larger, is on the lateral side of the groove; the *medial tubercle* is less prominent and lies immediately behind the sustentaculum tali of the calcaneum (fig. 476). The *inferior surface* rests on the upper surface of the calcaneum and is covered with an oval concave facet, the long axis of which runs forwards and laterally.

Particular features.—*The talus is devoid of any muscular attachments*, but it provides attachment for numerous ligaments (figs. 563 and 564), as it takes part in the formation of the ankle, the talocalcanean and the talocalcaneonavicular joints.

The long axis of the neck is inclined downwards and forwards and medially, making an angle of about 150° with the long axis of the body. This angle is smaller (130°-140°) in the newly-born child, and helps to account for the inverted position of the foot in young children. The dorsal surface of the neck gives attachment anteriorly to the dorsal talonavicular ligament and the anterior ligament of the ankle-joint; the posterior part of this surface therefore lies within the capsular ligament of the ankle-joint. The lateral part of the neck gives attachment to the anterior talofibular ligament, which extends downwards along the neighbouring anterior border of the lateral surface. The inferior surface of the neck gives attachment to the interosseous talocalcanean ligament, which is usually subdivisible into three parts (p. 509).

The *medial border of the trochlear articular surface* is straight but its *lateral border* inclines medially at its posterior part, which is often broadened and flattened to form a small elongated triangular area. It is this part of the bone which comes into contact with the inferior transverse tibiofibular ligament in dorsiflexion of the ankle-joint.

The *posterior tubercle* receives the attachment of the posterior talofibular ligament, which extends upwards to the groove, or depression, between the tubercle and the posterior border of the trochlea. Its lower border gives attachment to the posterior talocalcanean ligament. The *groove* between the posterior and medial tubercles lodges the tendon of the flexor hallucis longus and is continuous below and in front with the groove on the inferior surface of the sustentaculum tali. The *medial tubercle* gives attachment by its medial aspect to the medial talocalcanean ligament below, and to the most posterior of the superficial fibres of the deltoid ligament above.

The roughened area below the comma-shaped articular facet on the medial surface provides attachment for the deep fibres of the deltoid ligament.

The long axis of the posterior calcanean facet on the inferior surface of the body runs forwards and laterally at an angle of about 45° with the median plane. In about 10 per cent. of cases * a small pressure facet is found at the lateral end of the posterior wall of the sulcus tali; it is continuous with the anterolateral part of the posterior calcanean facet.

The Calcaneum (figs. 482–485)

General features.—The **calcaneum** is the largest and strongest of the tarsal bones; it projects backwards beyond the bones of the leg so as to provide a useful lever for the muscles of the calf, which are inserted into its posterior surface. It is irregularly cuboidal in shape, and its long axis is directed forwards, upwards and somewhat laterally. The student will experience no difficulty in distinguishing the small articular anterior end from the larger, roughened, posterior end, nor in dis-

* R. B. S. Sewell, *Journal of Anatomy and Physiology*, vol. xxxviii.

tinguishing the rough plantar surface from the upper surface, which bears a large, articular facet about its middle. Finally the lateral surface is flattened, whereas the medial surface is hollowed out from above downwards and backwards. The student should now be able to assign a calcaneum correctly to its appropriate side of the body.

The *upper surface* is subdivisible into three areas. The posterior third is roughened, convex from side to side and concave from behind forwards; it supports a mass of fibro-fatty tissue interposed between the tendo calcaneus and the back of the ankle-joint. The middle third is covered by the *posterior facet for the talus*, which is oval in outline and convex anteroposteriorly. The anterior third is partly articular and partly non-articular. In front of the posterior articular facet there is a rough depression, which becomes narrower and takes the form of a groove on the medial side. This is termed the *sulcus calcanei* or *groove of*

FIG. 482.—The left calcaneum. Superior aspect.

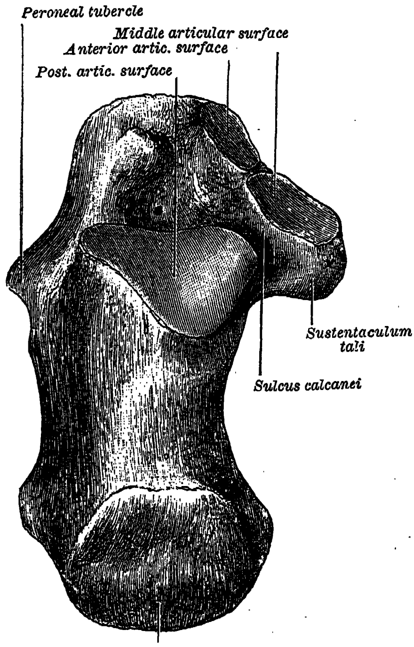
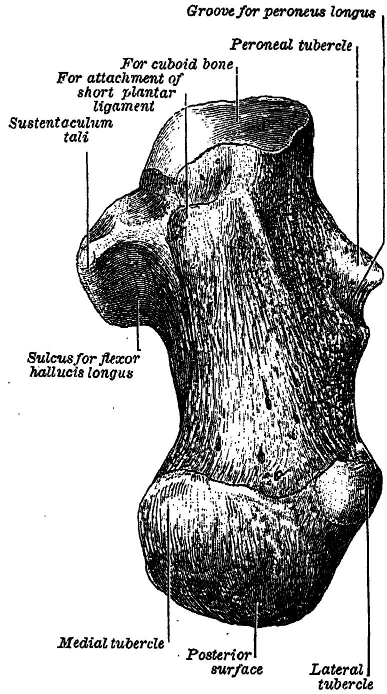


FIG. 483.—The left calcaneum. Plantar aspect.



the calcaneum; it corresponds to the sulcus tali and helps it to complete the sinus tarsi in the articulated foot. In front of and medial to this groove an elongated articular area covers the upper surface of a projecting shelf termed the sustentaculum tali, and extends forwards and medially on to the body of the bone. This area is not infrequently subdivided into two parts by a narrow non-articular interval which marks the anterior limit of the sustentaculum tali. They constitute the *middle* and *anterior facets for the talus*.

The *anterior surface* is the smallest of the six surfaces, and is entirely covered by an obliquely-set concavoconvex facet which articulates with the cuboid bone.

The *posterior surface* is divided into three areas. The uppermost is smooth and is separated from the tendo calcaneus by a bursa and some fatty tissue. The middle area is the largest; it is roughened to give insertion to the tendo calcaneus. The lowest area slopes downwards and forwards and is subcutaneous.

The *plantar surface* is rough and is marked by three tubercles. The *lateral* and *medial tubercles* are placed at the posterior part of this surface and are separated from each other by a slight notch. The medial tubercle is the larger of the two. Near the anterior part of this surface the *anterior tubercle* forms a rounded prominence which is separated from the anterior border by a narrow rough area.

The *lateral surface* is almost flat and is much deeper behind than in front. In its anterior part it presents a small elevation, termed the *peroneal tubercle*, which is exceedingly variable in its size. When well developed, it exhibits an oblique groove on its postero-inferior part, for the peroneus longus tendon, and a shallower groove on its anterosuperior aspect, for the peroneus brevis tendon. About 1 cm. or more behind the peroneal tubercle a second elevation may mark the bone; it gives attachment to part of the lateral ligament of the ankle-joint.

FIG. 484.—The left calcaneum. Lateral aspect.

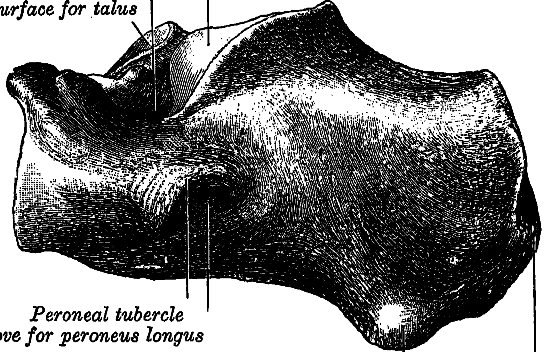
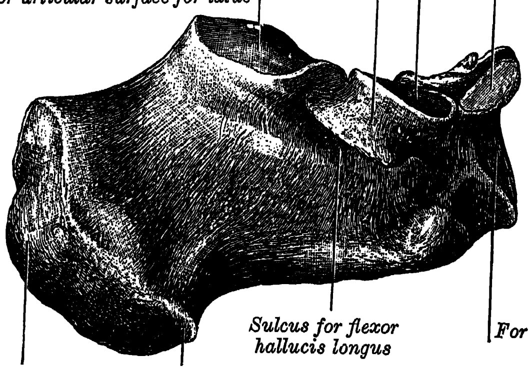


FIG. 485.—The left calcaneum. Medial aspect.



The *medial surface* is concave from above downwards and backwards, and its concavity is accentuated by a shelf-like process, termed the *sustentaculum tali*, which projects medially from the anterior part of its upper border (fig. 482). The superior surface of this process bears the middle facet for the talus, and its inferior surface is marked by a groove which is continuous with the groove on the posterior surface of the talus and lodges the flexor hallucis longus tendon. The medial surface of the sustentaculum tali can be felt indistinctly through the skin immediately below the tip of the medial malleolus; occasionally it presents a groove for the flexor digitorum longus tendon.

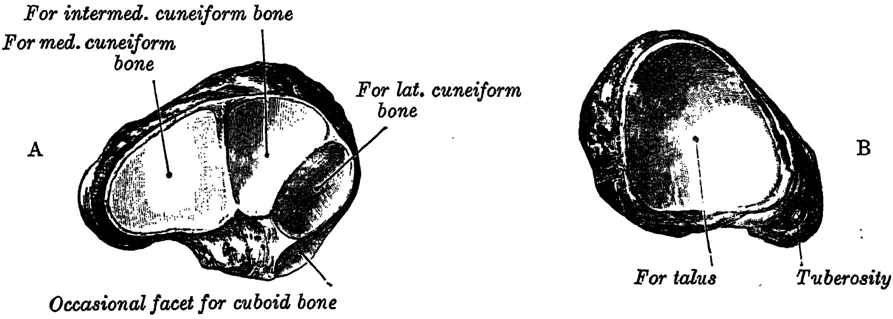
Particular features.—The *groove of the calcaneum* gives attachment to the interosseous talocalcanean ligament (p. 509). In addition, the non-articular area in front of the posterior facet for the talus gives partial origin to the extensor digitorum brevis and attachment to the principal band of the inferior extensor retinaculum (cruciate ligament) and to the stem of the bifurcated ligament.

The *medial tubercle* gives origin by its prominent medial margin to the abductor hallucis (fig. 477) and attachment to the superficial part of the flexor retinaculum (laciniate ligament), and in front to the plantar aponeurosis and the flexor digitorum brevis. The *lateral tubercle* gives origin to the abductor digiti minimi, which extends medially to arise from the front of the medial tubercle also. The roughened strip between the medial and lateral tubercles, behind, and the anterior tubercle, in front, gives attachment to the long plantar ligament, while the short plantar (plantar calcaneocuboid) ligament springs from the anterior tubercle and the narrow rough area in front of it (fig. 477). The lateral tendinous head of the flexor digitorum accessorius (quadratus plantæ) arises from the bone in front of the lateral tubercle close to the lateral margin of the long plantar ligament.

The *posterior surface* is wider below than above. Close to the medial side of the insertion of the tendo calcaneus it receives the insertion of the plantaris muscle.

The anterior part of the *lateral surface* is crossed by the tendons of the peroneus longus and brevis, but in most of its extent is covered only by the skin and superficial fascia. The peroneus brevis tendon, after passing behind the lateral malleolus, runs forwards and slightly downwards above and in front of the peroneal tubercle; the peroneus longus tendon passes downwards and forwards below and behind the tubercle, which gives attachment to a slip from the inferior peroneal retinaculum (p. 651). The calcaneofibular ligament is attached to the bone about 1 cm. or more behind the peroneal tubercle, and the site is usually indicated by a low rounded elevation.

FIG. 486.—The left navicular bone. A. Anterior aspect. B. Posterior aspect.



The *sustentaculum tali* assists, by its upper surface, in the formation of the talocalcaneonavicular joint; its lower surface is grooved by the flexor hallucis longus tendon, and the margins of the groove give attachment to the deep part of the flexor retinaculum (laciniate ligament). The medial margin of the process is a narrow roughened strip, convex from before backwards. Anteriorly it gives attachment to the plantar calcaneonavicular or 'spring' ligament (p. 511); behind that it gives attachment to a slip from the tibialis posterior tendon and to some of the superficial fibres of the deltoid ligament; its posterior part receives the medial talocalcanean ligament. Below the attachment of the deltoid ligament the tendon of the flexor digitorum longus is related to this aspect of the process and sometimes its position is indicated by a groove. Below the groove for the flexor hallucis longus the medial surface gives origin to the large, fleshy, medial head of the flexor digitorum accessorius (quadratus plantæ).

THE NAVICULAR BONE (fig. 486)

The **navicular bone** is situated in the medial part of the tarsus and is interposed between the head of the talus behind and the cuneiform bones in front.

The *anterior surface* is convex from side to side and is subdivided into three facets (of which the most medial is the largest) for articulation with the three cuneiform bones. The *posterior surface*, oval and concave, articulates with the head of the talus. The *superior surface* is roughened and is convex from side to side. The *medial surface* also is rough and is continued downwards to form a prominent projection termed the *tuberosity*. It can be felt through the skin about 2·5 cm. below and in front of the medial malleolus. The *plantar surface*, also roughened, is concave, and is separated from the tuberosity on the medial side by a groove. The

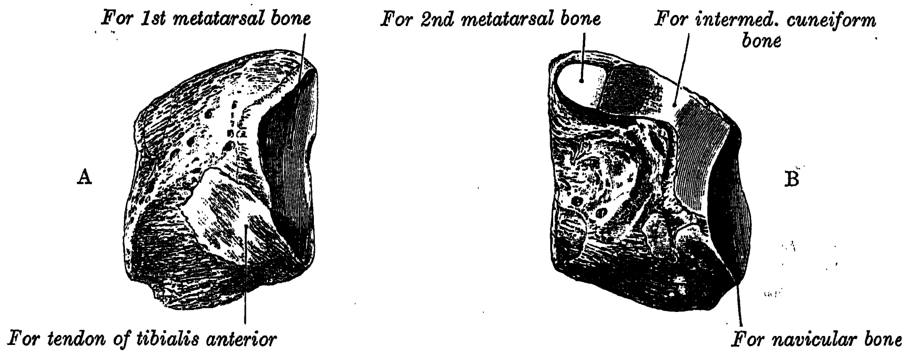
lateral surface is rough and irregular, but frequently presents a facet for articulation with the cuboid bone.

Particular features.—The facet for the medial cuneiform is triangular in outline, with its rounded apex on the medial side. The facets for the intermediate and lateral cuneiform bones are also triangular, but their apices lie inferiorly. The dorsal surface gives attachment to the dorsal talonavicular, cuneonavicular, and cubonavicular ligaments. The *tuberosity* of the navicular bone provides the principal insertion for the tibialis posterior tendon, and the groove which lies on its lateral side on the plantar surface transmits the part of this tendon which runs forwards to reach the cuneiform bones and the bases of the middle three metatarsal bones. A slight projection marks the plantar surface of the bone on the lateral side of the groove. Together with the posterior edge of this surface it gives attachment to the plantar calcaneonavicular or 'spring' ligament. The roughened part of the lateral surface gives attachment to the calcaneonavicular part of the bifurcated ligament.

THE CUNEIFORM BONES (figs. 487–489)

The **cuneiform bones**, three in number, are wedge-shaped and articulate with the navicular bone behind and the bases of the first, second and third metatarsal bones in front. The medial cuneiform bone is the largest of the three, and the intermediate the smallest. In the intermediate and in the lateral cuneiform bone the dorsal surface is the base of the wedge and the plantar surface represents the

FIG. 487.—The left medial cuneiform bone.
A. Medial aspect. B. Lateral aspect.



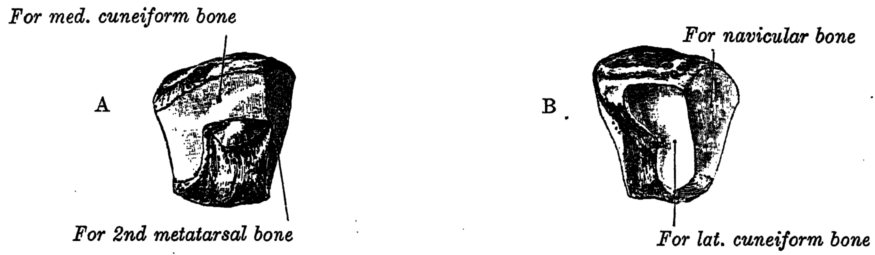
edge, but in the medial cuneiform bone the wedge is reversed so that its edge is represented by the narrow, dorsal surface of the bone. This arrangement is an important factor in the constitution of the transverse arch of the foot. The posterior surfaces of the three cuneiform bones form a slight concavity for the navicular bone, but the anterior parts of the medial and lateral cuneiforms project farther forwards than the intermediate cuneiform bone, and bound a deep recess in which the base of the second metatarsal bone is lodged.

Particular features.—The **medial cuneiform bone** (fig. 487) is the most medial bone of the distal row of the tarsus; it articulates with the navicular bone behind and with the base of the first metatarsal bone in front. The *dorsal surface* is rough and narrow, and represents the edge of the wedge. The *plantar surface* represents the base of the wedge; it receives a substantial slip from the tendon of the tibialis posterior muscle. The *anterior surface* bears a large kidney-shaped facet for articulation with the base of the first metatarsal bone, and the little notch which represents the hilum lies on its lateral margin. The *posterior surface* bears a piriform facet which articulates with the navicular bone. Concave from above downwards, it is narrower at its upper than at its lower end. The *medial surface* is rough and subcutaneous. It is slightly convex from above downwards and its antero-inferior angle is marked by a large, flattened impression which receives the insertion of most of the fibres of the tibialis anterior tendon. The *lateral surface* is partly articular and partly non-articular. Along its posterior and upper margins it is covered with an Γ-shaped smooth strip, which articulates with the intermediate cuneiform bone. The

upper and anterior part of this strip is separated by a vertical ridge from a small, almost square, facet which articulates with the upper part of the medial surface of the base of the second metatarsal bone. Below this facet the bone is attached to the medial side of the base of the second metatarsal bone by a strong interosseous ligament, and behind that the interosseous intercuneiform ligament connects it to the medial side of the intermediate cuneiform bone. The antero-inferior part of the lateral surface is roughened where it receives the insertion of part of the peroneus longus tendon.

FIG. 488.—The left intermediate cuneiform bone.

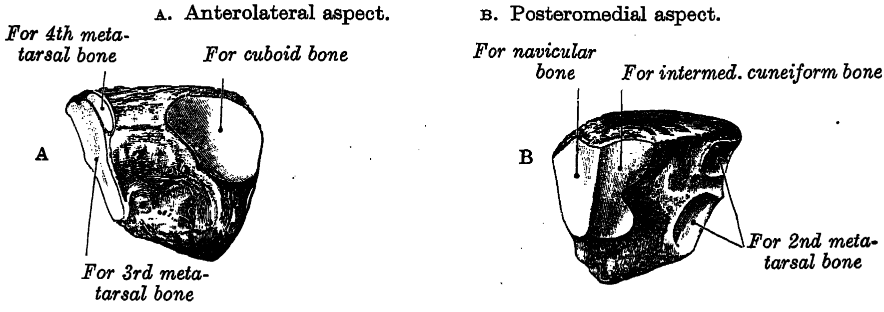
A. Anteromedial aspect. B. Posterolateral aspect.



The **intermediate cuneiform bone** (fig. 488) articulates in front with the base of the second metatarsal and behind with the navicular bone. It is of very regular wedge-like form, the base of the wedge forming the roughened, *dorsal surface*, and the edge the narrow, *plantar surface*, which receives a slip from the tibialis posterior tendon. The *anterior* and *posterior surfaces* are covered each with a triangular articular facet, for the base of the second metatarsal and the navicular bone, respectively. The *medial surface* is partly articular and partly non-articular. Along its posterior and upper margins it bears a Γ-shaped strip, occasionally subdivided into two parts, for articulation with the medial cuneiform. The

FIG. 489.—The left lateral cuneiform bone.

A. Anterolateral aspect. B. Posteromedial aspect.



lateral surface also is partly articular and partly non-articular. Along its posterior margin it bears a vertical strip, usually indented at its middle, for articulation with the lateral cuneiform bone. Strong interosseous ligaments connect the non-articular parts of the lateral and medial surfaces to the lateral and medial cuneiform bones.

The **lateral cuneiform bone** (fig. 489) is placed between the intermediate cuneiform and the cuboid bones. In front it articulates with the base of the third metatarsal and behind with the navicular bone. Like the intermediate cuneiform, its *dorsal surface*, rough and almost rectangular, represents the base of the wedge, and its *plantar surface*, narrow and rough, the edge. The latter receives a slip from the tibialis posterior tendon and may give partial origin to the flexor hallucis brevis. The *anterior surface* is completely covered with a triangular articular facet for the base of the third metatarsal bone. The *posterior surface* is rough in its lower part but is smooth and articular in its upper two-thirds, which articulate with the navicular by means of a triangular facet. The *medial surface* is partly articular and partly non-articular. Along its posterior margin it bears a vertical strip, indented at its middle, for the intermediate cuneiform bone, and along its anterior margin a narrower strip, often divided into two small facets, serves for articulation with the lateral aspect of the base of the second metatarsal bone. The *lateral surface* also is partly articular and partly non-articular. A large triangular or oval facet is situated posteriorly for

articulation with the cuboid bone; a small facet, semi-oval in shape, is placed at the upper part of its anterior margin for articulation with the dorsal part of the medial side of the base of the fourth metatarsal bone. The non-articular portions of the medial and lateral surfaces give attachment to strong interosseous intercuneiform and cuneocuboid ligaments, which play an important part in maintaining the transverse arch of the foot.

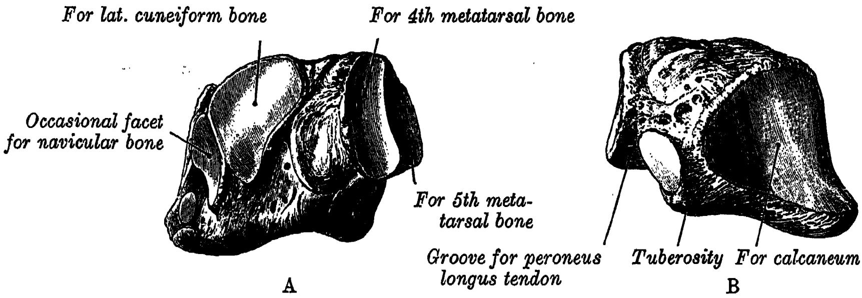
THE CUBOID BONE (fig. 490)

General features.—The **cuboid bone** is the most lateral bone of the distal row of the tarsus, and is situated between the calcaneum behind and the fourth and fifth metatarsal bones in front.

The *dorsal surface*, directed laterally as well as upwards, is rough for ligamentous attachments. The anterior part of the *plantar surface* is crossed by an oblique *groove for the peroneus longus tendon*, which is bounded behind by a prominent ridge. This ridge ends laterally in an enlargement termed the *tuberosity of the cuboid bone*. The lateral aspect of the tuberosity is faceted for the sesamoid bone or cartilage which is frequently found in the peroneus longus tendon. Behind the ridge the plantar surface is rough and, owing to the obliquity of the calcaneocuboid joint, extends backwards and medially so that the medial border of this surface is much

Fig. 490.—The left cuboid bone.

A. Anteromedial aspect. B. Posterolateral aspect.



longer than the lateral border. The *lateral surface* is rough and exhibits a deep notch which marks the commencement of the groove for the peroneus longus tendon. The *medial surface* is much more extensive and is partly articular and partly non-articular. It is marked near its middle by a smooth oval facet for articulation with the lateral cuneiform bone; behind this a small facet for the navicular bone is sometimes present. The two form a continuous articular surface but are separated by a vertical ridge. The *anterior surface* is divided by a vertical ridge into two articular areas; the medial facet is quadrilateral in form and articulates with the base of the fourth metatarsal bone; the lateral facet, triangular in outline with the apex on the lateral side, articulates with the base of the fifth metatarsal bone. The *posterior surface*—smooth, triangular and concavoconvex—articulates with the anterior surface of the calcaneum; its medial plantar angle projects backwards as a process which helps to support the anterior end of the calcaneum.

Particular features.—The dorsal surface gives attachment to the dorsal calcaneocuboid, cubonavicular, cuneocuboid and cubometatarsal ligaments. The ridge on the plantar surface gives attachment to the deep fibres of the long plantar ligament, which conceals the attachment of the short plantar (plantar calcaneocuboid) ligament to the posterior border of this surface. The projecting posteromedial part of the plantar surface receives a slip from the tendon of the tibialis posterior and gives origin to the flexor hallucis brevis muscle. The rough part of the medial surface of the cuboid affords attachment for the interosseous cuneocuboid and cubonavicular ligaments, and in its posterior part to the medial calcaneocuboid, which is the lateral limb of the bifurcated ligament.

The Homologies of the Carpus and the Tarsus.—In the most primitive reptiles the carpus and tarsus resemble one another very closely and, on the assumption that the radius, which

is the pre-axial bone of the forearm, is homologous with the tibia, which is the pre-axial bone of the leg—a view which is generally but not universally accepted—little difficulty is experienced in determining the homologies of their constituent elements. In man the carpus remains relatively primitive and the identification of its elements in the reptilian carpus is a comparatively simple problem. Owing to the adoption of the erect attitude the human tarsus has been modified very considerably, and it is only by reference to the primitive reptilian condition that any clue can be obtained to the homologies of the carpal and tarsal bones.

The following tabular statement presents the view which has obtained most support.

Reptilian Carpus.	*Human Carpus.*	*Reptilian Tarsus.*	*Human Tarsus.*
Os radiale	Scaphoid bone (less its tubercle)	Os tibiale	Talus
Os intermediale	Lunate bone	Os intermediale	(Os trigonum)
Os ulnare	Triquetral bone	Os fibulare	Calcaneum
Ossa centralia (1 and 2)	Tubercle of the scaphoid bone	Ossa centralia (1 and 2)	Navicular bone
Os carpale 1	Trapezium bone	Os tarsale 1	Medial cuneiform bone
„ „ 2	Trapezoid bone	„ „ 2	Intermediate cuneiform bone
„ „ 3	Capitate bone	„ „ 3	Lateral cuneiform bone
„ „ 4 and 5	Hamate bone	„ „ 4 and 5	Cuboid bone

THE METATARSUS

The **metatarsal bones**, five in number, are situated in the anterior part of the foot in front of the tarsus and behind the phalanges. They are numbered from the medial to the lateral side.

The Common Characters of the Metatarsal Bones

Like the metacarpals, the metatarsals are miniature long bones, and each possesses a shaft, a base or proximal end, and a head or distal end.

With the exception of the first and, to a lesser degree, the fifth, the **shafts** are long and slender, and are slightly convex longitudinally on their dorsal aspects and concave on their plantar aspects. They are prismoid in form and taper from the base to the head.

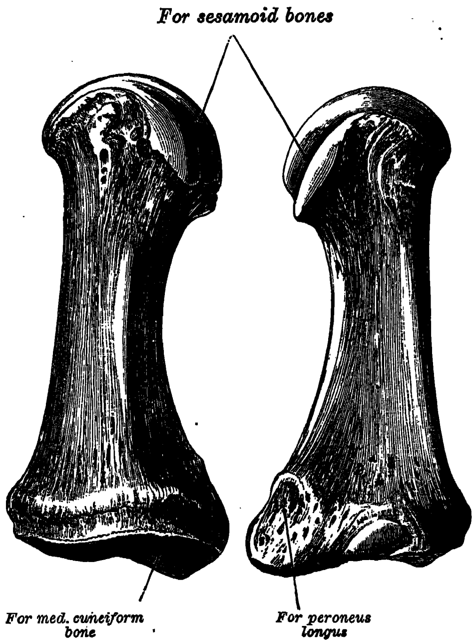
The **bases** articulate with the distal row of the tarsus and with one another. The line of each tarsometatarsal joint, excluding the first, passes backwards and laterally, and the bases of the metatarsals are therefore set somewhat obliquely relative to their shafts—a fact which assists in the recognition of the side of the body to which the bones belong.

The **heads** articulate with the proximal phalanges of their own digits, each by means of a convex articular surface which extends farther on the plantar than on the dorsal surface; the plantar extension ends on each side on the summit of a slight eminence. The sides of the heads are flattened, and each shows a depression surmounted dorsally by a tubercle, which gives attachment to one of the collateral ligaments of the metatarsophalangeal joint.

The Characters of the Individual Metatarsal Bones

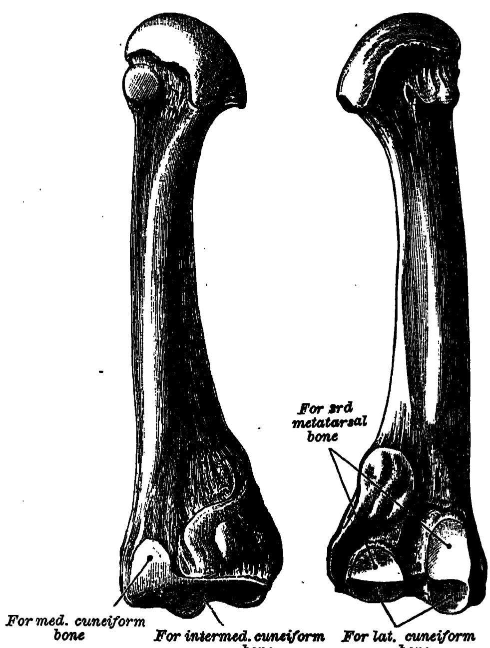
The first metatarsal bone (fig. 491) is the shortest and thickest of the metatarsal bones. The *body* is strong, and of well-marked prismoid form. The *base* has no articular facets on its sides, but there is occasionally a pressure facet on the lateral side caused by contact with the second metatarsal bone. Its posterior surface, of large size and kidney-shaped, articulates with the first cuneiform bone; the lateral border of the facet shows a slight indentation, which represents the hilum of the kidney. Its circumference is grooved for the tarsometatarsal ligaments, and medially gives insertion to a part of the tendon of the tibialis anterior; its plantar angle presents a rough, oval prominence for the insertion of

FIG. 491.—The left first metatarsal bone Medial and lateral aspects.



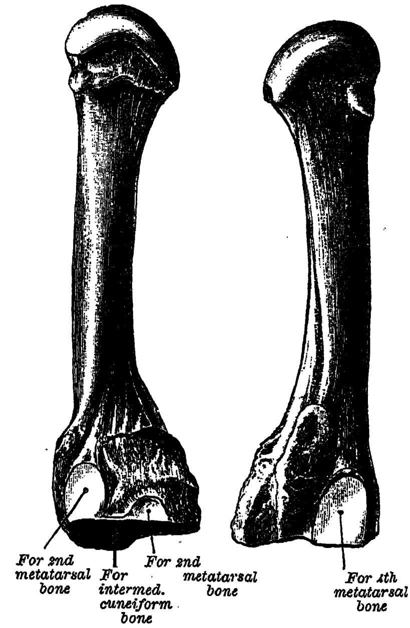
the tendon of the peroneus longus. The lateral surface of the shaft is flat and gives origin to the medial head of the first dorsal interosseous muscle. The *head* is large; on its plantar surface there is a median elevation separating two grooved facets on which sesamoid bones glide.

FIG. 492.—The left second metatarsal bone. Medial and lateral aspects.



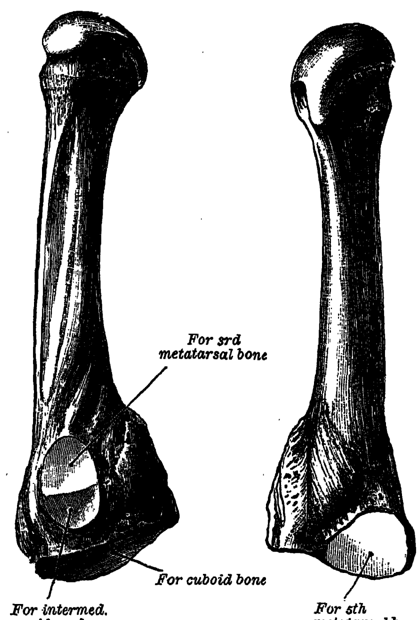
The second metatarsal bone (fig. 492) is the longest of the metatarsal bones. Its wedge-shaped *base* bears four articular facets: one on its posterior surface, of a triangular form, for articulation with the intermediate cuneiform bone; one at the upper part of its medial surface, for articulation with the medial cuneiform bone; and two on its lateral surface,

FIG. 493.—The left third metatarsal bone. Medial and lateral aspects



an upper and a lower, separated by a rough non-articular interval. Each of these lateral articular surfaces is divided by a vertical ridge; the anterior two facets articulate with the third metatarsal bone; the posterior two (sometimes continuous) with the lateral cuneiform bone. A pressure facet is occasionally present caused by contact with the first metatarsal

FIG. 494.—The left fourth metatarsal bone. Medial and lateral aspects.

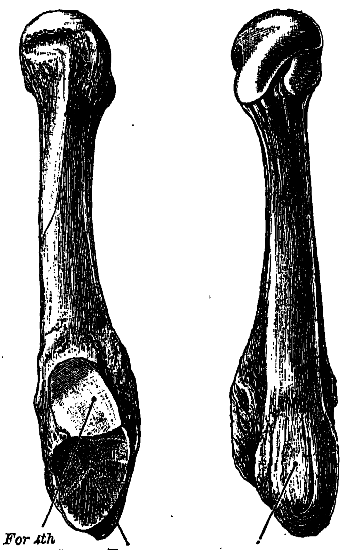


bone; it is oval in shape, and is situated on the medial side of the base, in front of the facet for the medial cuneiform bone. The medial and lateral surfaces of the shaft give origin respectively to the lateral head of the first dorsal interosseous muscle and the medial head of the second.

The **third metatarsal bone** (fig. 493) has a triangular *base*, which articulates posteriorly with the lateral cuneiform bone; medially it articulates by two facets with the second metatarsal bone; and laterally, by a single facet situated at the dorsal angle, with the fourth metatarsal bone. The medial surface of the shaft gives origin to the lateral head of the second dorsal interosseous muscle and to the first plantar; the lateral surface gives origin to the medial head of the third dorsal interosseous muscle.

The **fourth metatarsal bone** (fig. 494) is smaller than the third. The posterior surface of its *base* bears an oblique quadrilateral facet for articulation with the cuboid bone; on its lateral side a single facet, for the fifth metatarsal bone; on its medial side a facet

FIG. 495.—The left fifth metatarsal bone. Medial and lateral aspects.



divided by a ridge into an anterior portion for the third metatarsal bone, and a posterior portion for the lateral cuneiform bone. The medial surface of the shaft gives origin to the lateral head of the third dorsal interosseous muscle and to the second plantar; the lateral surface gives origin to the medial head of the fourth dorsal interosseous muscle.

The **fifth metatarsal bone** (fig. 495) is recognised by a rough eminence, termed the *tubercle*, on the lateral side of its base. The *base* articulates posteriorly with the cuboid bone by a triangular, obliquely cut surface; and medially, with the fourth metatarsal bone. The tendon of the peroneus tertius is inserted on the medial part of its dorsal surface, and that of the peroneus brevis on the dorsal surface of the tubercle. A strong band of the plantar aponeurosis connects the projecting part of the tubercle with the lateral tubercle of the calcaneum. The plantar surface of the base is grooved by the tendon of the abductor digiti minimi, and gives origin to the flexor digiti minimi brevis. The medial side of the shaft gives origin to the lateral head of the fourth dorsal interosseous muscle and to the third plantar.

The Phalanges of the Foot (Phalanges Digitorum Pedis)

The **phalanges** of the foot correspond in number and general arrangement with those of the hand; there are two in the big toe, and three in each of the other toes. They are, however, much smaller, and their shafts, especially those of the bones of the first row, are compressed from side to side.

The **proximal phalanges** closely resemble those of the hand. The *shaft* of each is compressed from side to side, convex above, concave below. The *base* is concave for articulation with the head of the corresponding metatarsal bone, and the *head* possesses a trochlear surface for articulation with the middle phalanx.

The **middle phalanges** are remarkably small and short, but rather broader than the proximal phalanges.

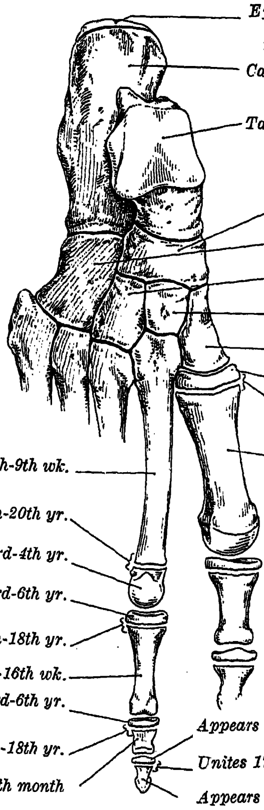
The **distal phalanges** resemble those of the fingers; but they are smaller, and are flattened from above downwards; each presents a broad base for articulation with the

corresponding middle phalanx, and an expanded distal extremity for the support of the nail and the end of the toe. Each bears a roughened *tuberosity* on the plantar aspect of its distal end.

Ossification of the Bones of the Foot (fig. 496)

The **tarsal bones** are ossified each from a single centre, excepting the calcaneum, which has a scale-like epiphysis for its posterior part. The centres make their appearance as follows: in the calcaneum, at the sixth month of intrauterine life; in the talus, about the seventh month; in the cuboid, at the ninth month; in the lateral cuneiform, during the first year; in the medial cuneiform, during the third year; in the intermediate cuneiform and navicular, during the fourth year. The epiphysis for the posterior part of the calcaneum begins to ossify between the sixth and tenth years, and unites with the rest of the bone

Fig. 496.—A plan of the ossification of the bones of the foot.



soon after puberty. The posterior tubercle of the talus is sometimes ossified from an independent centre, and may then remain separate or it may be connected to the rest of the bone by cartilage. This additional ossicle is named the *os trigonum*.

The **metatarsal bones** are ossified each from two centres: a primary centre for the shaft, and a secondary or epiphyseal centre for the base or proximal end of the first, and for the head or distal end of each of the other four.* Ossification begins in the middle of the shaft about the eighth or ninth week of intrauterine

* As in the first metacarpal bone (see page 366), so in the first metatarsal, there is sometimes a second epiphysis for the head.

life. The epiphysis for the base of the first metatarsal appears about the third year; those for the heads of the other metatarsals between the third and fourth years; all unite with the shafts between the seventeenth and twentieth years. An epiphysis is frequently present on the tubercle of the base of the fifth metatarsal bone (Holland).*

The phalanges are each ossified from two centres: a primary one for the shaft and an epiphysis for the base. The primary centres for the distal phalanges appear about the eighth week of intrauterine life: those for the proximal phalanges between the twelfth and sixteenth weeks, and those for the intermediate phalanges after the sixteenth week (that for the phalanx of the fifth toe

Fig. 497.—The skeleton of the left foot. Medial aspect.

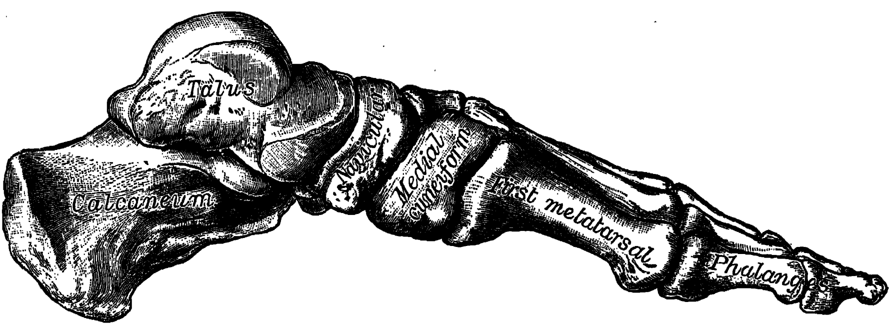
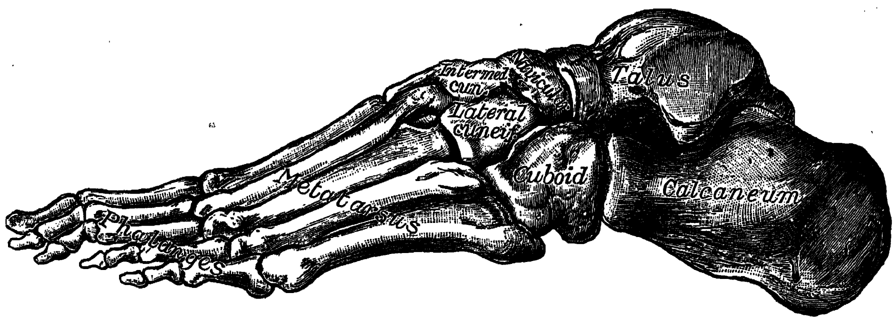


Fig. 498.—The skeleton of the left foot. Lateral aspect.



does not usually appear until after birth). The epiphyseal centres appear between the third and sixth years, and unite with the shafts about the seventeenth or eighteenth year.

Comparison of the Bones of the Hand and Foot

The hand and foot are constructed on similar principles—each comprising a proximal part, the carpus or tarsus, an intermediate portion, the metacarpus or metatarsus, and a distal portion, the phalanges. The proximal part consists of a series of more or less cubical bones which allow a slight amount of gliding on one another and are chiefly concerned in distributing forces transmitted to or from the bones of the forearm or leg. The intermediate part is made up of slightly movable long bones, which assist the carpus or tarsus in distributing forces, and also give greater breadth for the reception of such forces. The separation of the individual bones from one another allows of the attachments of the interosseous muscles and protects the dorsipalmar

* C. Thurstan Holland, *Journal of Anatomy*, vol. lv. 1921.

and dorsiplantar vascular anastomoses. The distal portion is the most movable, and its separate elements enjoy a varied range of movements, the chief of which are flexion and extension.

The functions of the hand and foot are, however, very different, and the general similarity between them is greatly modified to meet these requirements. Thus, the foot forms a firm basis of support for the body in the erect posture, and is therefore more solidly built, and its component parts are less movable on each other than those of the hand. The architecture of the bones of the hand is designed to provide an efficient instrument of prehension, and its component parts are not only capable of a greater range of movement but possess a greater degree of independent mobility. In the case of the proximal phalanges the difference is readily noticeable; those of the foot are smaller and their movements more limited than those of the hand. The difference between the metacarpal bone of the thumb and the metatarsal bone of the big toe is very much more marked. The position of the metacarpal bone of the thumb permits of great mobility; as compared with the other metacarpal bones, it is carried forwards and rotated round its long axis through an angle of approximately 90°, and it is capable of a considerable range of movement at its articulation with the carpus. The metatarsal bone of the big toe assists in supporting the weight of the body, is constructed with great solidity, lies parallel with the other metatarsals, and has a limited degree of movement. The carpus is small in proportion to the rest of the hand, is placed in line with the forearm, and forms a transverse arch, the concavity of which constitutes a bed for the flexor tendons. The tarsus forms a considerable part of the foot, and is placed at right angles to the leg, a position which is almost peculiar to man, and has relation to his erect posture. In order to allow of their supporting the weight of the body efficiently while making provision for the requisite spring and elasticity of the gait, the tarsus and metatarsus are built up into a series of arches (figs. 497, 498), the disposition of which will be considered after the articulations of the foot have been described.

THE SESAMOID BONES *

The **sesamoid bones** are more or less rounded nodules of bone imbedded in certain tendons and usually related to articular surfaces. Their functions probably are to modify pressure, to diminish friction, and occasionally to alter the direction of the pull of a muscle. The fact that they are present as cartilaginous nodules in the fœtus and in greater numbers than in the adult shows that they are not developed to meet certain physical requirements in the adult. They must be regarded as integral parts of the skeleton phylogenetically inherited.† Physical necessities probably come into play in selecting and in regulating the degree of development of the original cartilaginous nodules.

Sesamoid bones are invested by the fibrous tissue of the tendons, except on the surfaces in contact with the parts over which they glide, where they present smooth articular facets.

In the upper limb the sesamoid bones of the joints are found only on the palmar surface of the hand. Two, of which the medial is the larger, are present at the metacarpophalangeal joint of the thumb, imbedded in the tendons of the adductor pollicis and the flexor pollicis brevis; one is frequently present in the corresponding joint of the index finger, and one (or two) in the same joint of the little finger. Sesamoid bones are found occasionally imbedded in the palmar ligaments at the metacarpophalangeal joints of the middle and ring fingers, at the interphalangeal joint of the thumb, and at the distal interphalangeal joint of the index finger.

In the lower limb the largest sesamoid bone of the joints is the patella, developed in the tendon of the quadriceps femoris. On the plantar aspect of the foot, two, of which the medial is the larger, are always present at the metatarsophalangeal joint of the big toe, imbedded in the tendons of insertion of the flexor hallucis brevis; one sometimes at the metatarsophalangeal joints of the second and fifth toes, one

* Consult an article by A. H. Bizarro, *Journal of Anatomy* vol. lv. 1921.

† Thilenius, *Morpholog. Arbeiten*, v. 1896.

occasionally at the corresponding joints of the third and fourth toes, and one at the interphalangeal joint of the big toe.

Sesamoid bones apart from joints are seldom found in the tendons of the upper limb; one is sometimes seen in the tendon of the biceps opposite the radial tuberosity. Sesamoid bones or cartilages are, however, present in several of the tendons of the lower limb—viz. one in the tendon of the peroneus longus where it glides on the cuboid bone; one, appearing late in life, in the tendon of the tibialis anterior, opposite the smooth facet on the anteromedial part of the medial surface of the medial cuneiform bone; one in the tendon of the tibialis posterior, opposite the medial side of the head of the talus; one in the lateral head of the gastrocnemius, behind the lateral condyle of the femur; and one in the tendon of the psoas major where it glides over the ilium. Sesamoid bones are found occasionally in the tendons which wind round the medial and lateral malleoli, and one is sometimes present in the tendon of the gluteus maximus where it passes over the greater trochanter of the femur.

ARTHROLOGY

A *JOINT* or *articulation* is formed where two or more bones of the skeleton meet one another. In long bones the ends are the parts which form the joints: in flat bones the joints usually are formed at the edges: and in short and irregular bones the joints may occur at various parts of their surfaces.

The function of the joint is the most important factor in the determination of its character and structure. In some situations, e.g. in the skull, it is important that no movement should be permitted between contiguous bones; in other situations, e.g. in the vertebral column, a slight degree of mobility is advantageous, provided that it can be obtained without any loss of strength; and in still other situations the provision of a more or less wide range of movement is all-important.

In the earlier sections the development of the skeletal system and its component parts has been described, and it has been shown how in the first place the individual bones are laid down as condensations of the mesenchyme. Later, adjoining areas of condensation may become continuous with one another before they undergo the processes of chondrification and ossification. Centres of chondrification and ossification appear and outline the individual bones, which are connected to one another by plates of mesenchyme. The subsequent history of this mesenchymal plate differs in different types of joint. It may become converted into white fibrous tissue; it may be converted into cartilage; or it may break down and leave a space between the two opposed bones. In the first case the connecting medium between the bones concerned is white fibrous tissue, made up of numbers of bundles of short, white connective tissue fibres running between the opposing ends: such joints are immovable and are termed *fibrous joints*. In the second case the connecting medium between the bones concerned is white fibrocartilage; such joints are capable of a limited range of movement, and are termed *cartilaginous joints*. In the third case the opposed bones are separated from one another by a space, lined by a special membrane which is termed synovial membrane; the joint possesses a more or less wide range of movement and is termed a *synovial joint*.

In joints where only a slight degree of movement is required, the desired result is obtained by the provision of a cartilaginous joint when adequate leverage is available, e.g. in the joints between the bodies of the vertebræ. In some situations, however, e.g. in the joints of the carpus and metacarpus, the necessary leverage cannot be obtained and synovial joints are essential to provide even very limited degrees of movement.

All the joints in the human body fall into one of these three categories, and the salient features of each group must be considered, before the individual joints of the body can be described in detail.

A CLASSIFICATION OF THE JOINTS

Joints are divided into three classes: *fibrous joints, cartilaginous joints,* and *synovial joints.*

1. Fibrous Joints. [Articulationes Fibrosæ]

Fibrous joints are articulations in which the surfaces of the bones are fastened together by intervening fibrous tissue, and in which there is no appreciable motion, as in the joints between the bones of the cranium. There are two principal groups of fibrous joints: sutures and syndesmoses. Sutures, however, can be subdivided into seven different varieties.

A **suture** is an articulation met with only in the skull, where the margins of

the bones articulate with one another (fig. 499), but are separated by a thin layer of fibrous tissue, which is named the *sutural ligament* and is continuous externally with the periosteum on the outside of the skull (pericranium), internally with the fibrous layer of the dura mater (the membrane which covers the brain).

When the bony margins are provided with saw-like edges the articulation is named *sutura serrata*, as in the sagittal suture. When the margins present a series of tooth-like processes which widen towards their free ends, the articulation is named a *denticulate suture*. Where one bone overlaps another, as in the suture between the temporal and parietal bones, it is named *sutura squamosa*; where the overlapping edges are ridged or serrated it is named *sutura limbosa*;

Fig. 499.—A section through the sagittal suture.

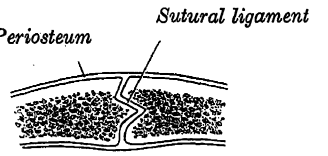
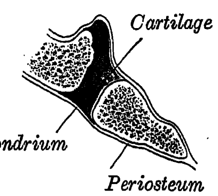


Fig. 500.—A section through the spheno-occipital joint of an infant.



where there is simple apposition of contiguous rough surfaces, as between the palatine processes of the maxillæ, or between the horizontal plates of the palatine bones, it is named *sutura plana*.

A *gomphosis* or *peg-and-socket suture* is articulation by the insertion of a conical process into a socket; it is seen in the articulations of the roots of the teeth with the alveoli of the mandible and maxillæ. A *schindylesis* or *wedge-and-groove suture* is a joint where a ridge fits into a grooved surface; it is seen in the articulation between the rostrum of the sphenoid and the upper border of the vomer.

Syndesmosis is a joint in which the opposed bony surfaces are connected by an interosseous ligament, as in the inferior tibiofibular joint.

2. Cartilaginous Joints. [Articulationes Cartilagineæ]

In these articulations the opposed bony surfaces are connected to each other by cartilage, and a limited amount of movement may be possible. There are two varieties of cartilaginous joints, viz. primary and secondary.

Primary cartilaginous joint.—This is usually a temporary form of joint, for the connecting cartilage, which is hyaline in character, is, in most cases, converted ultimately into bone. Primary cartilaginous joints are found between the epiphyses and diaphyses of long bones, between the occipital and sphenoid bones at and for some years after birth, and between the petrous parts of the temporal bones and the jugular processes of the occipital bone. No movement is permitted at these joints, for the cartilaginous plate is relatively thin and the necessary leverage cannot be obtained.

Secondary cartilaginous joint.—In this joint the opposed bony surfaces are covered with hyaline cartilage, and are connected to each other by a flattened disc of fibrocartilage of a more or less complex structure (fig. 501). The bones are also connected by bands of white fibrous tissue termed ligaments, which, however, do not form a complete capsule round the joint. A limited degree of movement is permitted and it is rendered possible by the compressibility of the cartilaginous disc and the degree of leverage which is available. Secondary cartilaginous joints are represented by the joints between the vertebral bodies, the joint between the manubrium and the body of the sternum, and the joint between the pubic bones (pubic symphysis). All these articulations lie in the median plane of the body.

3. Synovial Joints. [Articulationes Synoviales]

Most of the joints of the body, *including all the joints of both limbs,* with the exception of the inferior tibiofibular syndesmosis and the pubic symphysis,

belong to the synovial group. They have certain definitely characteristic features. (1) The contiguous bony surfaces are covered with articular cartilage and are not attached to one another. (2) There is a joint cavity, which is reduced to a potential space in the normal healthy condition during life. (3) The joint is completely surrounded by an articular capsule, which consists of a capsular ligament lined with a synovial membrane. (4) The synovial membrane lines the whole of the interior of the joint with the exception of the cartilage-covered ends of the articulating bones. (5) The bones are usually connected by a variable number of ligaments which are additional to the capsular ligament and usually superficial to it. (6) On account of the nature of the connexions between the bones concerned, movement is always possible in a synovial joint: it may vary from a simple gliding movement, very limited in range, such as is permitted between the individual bones of the carpus, to the wide range of movement of the shoulder-joint.

In addition, the joint-cavity may be divided, completely or incompletely, by an *articular disc* of fibrocartilage (fig. 503). These structures act as shock-reducing agents and they serve to ensure perfect contact between the moving surfaces in any position of the joint (p. 429). The periphery of articular discs is continuous with the capsular ligament of the joint, while their free surfaces are covered with synovial membrane, unless they are subjected to pressure, as in the knee-joint.

The **articular cartilage** which covers the articular surface of a bone is usually hyaline in character, but in the cases of bones which ossify in membrane it may be white fibrocartilage. It contains neither nerves nor blood-vessels, and its nutrition is derived from the vascular network in the synovial membrane at its periphery, and to a certain extent from the synovia which lubricates the joint (*vide infra*). Macroscopically its free surface is smooth and has no covering perichondrium; microscopically the surface is finely irregular, and minute shred-like projections indicate the effects of normal wear and tear. The deepest part of the articular cartilage is calcified and is firmly attached to the articular surface of the bone, which is formed by a compact layer termed the *articular lamella*. The lacunæ of this lamella are large but no Haversian canals or canaliculi are present. The vessels of the neighbouring spongy substance approach the articular lamella but do not perforate it, so that it is denser and firmer than ordinary bone.

The **capsular ligament** consists of parallel and interlacing bundles of white connective tissue fibres. It forms a sort of cuff or brassard, each end of which is attached to a continuous line around the articular end of one of the bones concerned, usually in the immediate neighbourhood of the periphery of the articular surface, but this arrangement is subject to considerable variation. It is perforated by the articular vessels and nerves, and may present one or more apertures through which the synovial membrane protrudes to form a pouch or sac. The capsular ligament usually shows two or more localised thickenings in which the constituent fibre bundles are generally parallel to one another. These thickenings are the **ligaments of the joint** and they are named according to their position or attachments. In some joints the capsular ligament is reinforced or replaced by the tendons, or by expansions from the tendons, of neighbouring muscles. Some joints possess accessory ligaments which stand clear of the capsular ligament. Such accessory ligaments may be situated outside the capsule, or they may be intracapsular.

All ligaments are tough, inelastic and unyielding, but at the same time flexible and pliant, so that they offer no resistance to normal movements. On the other hand they are designed to prevent the occurrence of excessive or abnormal movements, and every ligament becomes taut at the normal limit of some particular movement. They are not designed to withstand prolonged tension, and pain always results when they are subjected to it.

The **synovial membrane** lines the capsular ligament and covers those parts of the bones which are within the capsule, but ceases at the margins of the articular cartilages, which it usually overlaps to a slight extent. It gives a covering to all intracapsular structures, e.g. tendons, ligaments or articular discs, with certain important exceptions. The semilunar cartilages of the knee-joint, which are subjected normally to considerable pressure, have no

synovial covering although they are clothed with synovial membrane in the fœtus; and an area on the anterior part of the capsular ligament of the hip-joint corresponding to the front of the head of the femur is devoid of synovial lining. In many joints the synovial membrane forms fringe-like processes, usually containing small pads of fat, which project into the interior and fill up any irregularities or potential spaces in the joint (fig. 533). The synovial membrane secretes a small quantity of viscid glairy fluid termed *synovia.* This fluid acts as a lubricant and may help to nourish the articular cartilage. It contains small percentages of salts, albumen, extractives, etc., some of which are no doubt contributed by the wearing away of the articular cartilage.

Histologically the synovial membrane is composed of a delicate, vascular, connective tissue, which is covered on its free surface by an incomplete layer

FIG. 501.—A section through a secondary cartilaginous joint. Diagrammatic.

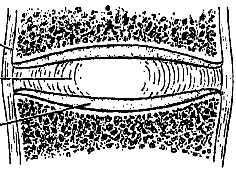


FIG. 502.—A section through a simple synovial joint. Diagrammatic.

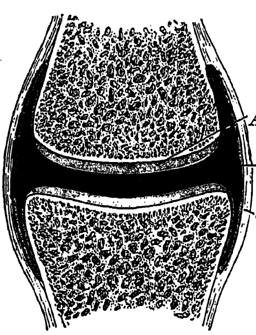
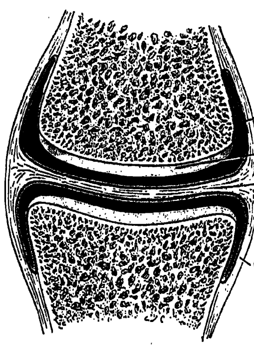


FIG. 503.—A section through a synovial joint with an articular disc. Diagrammatic.



of flattened cells, resembling an endothelium. The collagenous groundwork of the tissue is traversed by numerous fine fibres and contains many connective tissue cells of different types. The cell elements of the synovial membrane are migratory and highly phagocytic. They may be present in the synovia, and are capable of absorbing micro-organisms and foreign particles injected into the joint. In addition, they probably absorb the cartilaginous debris which must result from ordinary wear and tear.

The synovial sheaths of tendons (vaginæ mucosæ) and the synovial bursæ (bursæ mucosæ) are closely related in structure and function to the synovial membrane of joints.

Classification.—Synovial joints are classified according to the kind of motion permitted in them. There are two varieties in which the movement is uniaxial; that is to say, all movements take place around one axis. In one, the *ginglymus* or *hinge-joint,* this axis is, practically speaking, transverse; in the other, the *articulatio trochoidea* or *pivot-joint,* it is longitudinal. There are two varieties where the movement is bi-axial; these are the *articulatio condyloidea* or *condyloid joint* and the *articulatio sellaris* or *saddle-joint.* There is one form where the movement is poly-axial, the *articulatio cotylica* or *ball-and-socket joint*; and finally there is the *articulatio plana* or *plane joint.*

In uni-axial and poly-axial joints it is not difficult, from the mechanical point of view, to ensure that the opposed articular surfaces shall make perfect contact in all positions of the joint, but the same object is by no means easy to

attain in biaxial joints, where movements are possible around two axes which are at right angles to each other. In many situations this difficulty is overcome by the provision of articular discs. The opposite surfaces of a disc do not correspond to each other, but each is accurately adapted to the bone with which it is in contact. When movement occurs round one of the two axes, the disc remains stationary relative to one of the bones but moves with it over the other; when movement occurs round the other axis, the disc remains stationary relative to the opposite bone and moves with it. For example, when the sternal end of the clavicle is elevated or depressed, the clavicle moves over the clavicular surface of the articular disc of the joint, but when the bone is moved forwards or backwards, the disc remains stationary relative to the clavicle and moves with it over the clavicular notch of the manubrium sterni. This arrangement ensures perfect contact between the bones and the disc in all positions of the joint, and in this sense, the discs may be said to adapt the opposed articular surfaces to each other.

Ginglymus or **hinge-joint.**—In this form the articular surfaces are moulded to each other in such a manner as to permit motion in one plane only. On each side of the articular surfaces the bones are connected together by strong collateral ligaments, which form their chief bond of union. The best examples of hinge-joints are the interphalangeal joints, and the joint between the humerus and ulna.

Articulatio trochoidea or **pivot-joint.**—Where the movement is limited to rotation, the joint is formed by a pivot turning within a ring, or a ring turning on a pivot, the ring being formed partly of bone, partly of ligament. In the superior radio-ulnar joint, the ring is formed by the radial notch of the ulna and the annular ligament; here, the head of the radius rotates within the ring. In the articulation of the odontoid process (dens) of the axis with the atlas, the ring is formed in front by the anterior arch, and behind by the transverse ligament, of the atlas; here, the ring rotates round the odontoid process.

Condyloid articulation.—In this form of joint, an ovoid, convex, articular surface, or condyle, is received into an elliptical concavity in such a manner as to permit of active flexion, extension, adduction, abduction and circumduction, but no active axial rotation. The radiocarpal joint is an example of this form of articulation. (*See also* p. 473.)

Saddle-articulation.—In this variety the opposing surfaces are reciprocally concavoconvex, and the movements are the same as in the preceding form. The best example of the saddle-articulation is the carpometacarpal joint of the thumb.

Articulatio cotylica or **ball-and-socket joint.**—In this type of joint the distal bone is capable of motion around an indefinite number of axes, which have one common centre. It is formed by the reception of a globular head into a cup-like cavity, hence the name 'ball-and-socket.' Examples of this form of articulation are found in the hip- and shoulder-joints.

A **plane joint** is one which admits of gliding movement only; it is formed by the apposition of plane, or nearly plane, surfaces, the amount of motion in such joints being limited by the ligaments or osseous processes surrounding the articulations. It is seen in the joints between the articular processes of the vertebræ, and in most of the carpal and tarsal joints.

The Kinds of Movement permitted in Joints

The movements permitted in joints may be divided into four kinds: gliding and angular movements, circumduction, and rotation. Frequently these are more or less combined in the various joints, so as to produce an infinite variety, and it is seldom that only one kind of motion is found in any particular joint. Where movement is limited in range, the reciprocal articular surfaces are approximately equal in size, but where movement is free, they show considerable differences, the more movable bone usually possessing the larger surface.

Gliding movement is the simplest kind of motion that can take place in a joint, one surface gliding over another without any angular or rotatory movement. It is common to most movable joints; but in some, as in most of the articulations of the carpus and tarsus, it is the only motion permitted. This

movement is not confined to plane surfaces, but may take place between any two contiguous surfaces, of whatever form.

Angular movement implies diminution, or increase, of the angle between adjoining bones. Two types of angular movement are so common, especially in the joints of the limbs, that they must be defined. They occur around axes which are set at right angles to each other and are : (1) *flexion* and its opposite, *extension*, and (2) *abduction* and its opposite, *adduction*.

Flexion occurs around an axis which is transverse or obliquely transverse, and usually results in the approximation of two morphologically ventral surfaces. This definition is not entirely satisfactory, for its first part does not hold good for the joints of the thumb ; and its second part, in the cases of the shoulder, hip and ankle joints. The thumb lies in a plane set at right angles to the plane of the fingers. As a result its dorsal surface is directed laterally, and flexion and extension at each of its joints occur around an anteroposterior axis. At the shoulder-joint flexion carries the arm forwards and medially, and its morphologically ventral surface is brought no nearer to the ventral aspect of the trunk. At the hip-joint, owing to the changes which occur in the early stages of development (p. 101), flexion approximates the morphologically dorsal surface of the thigh to the ventral surface of the trunk. The condition at the ankle-joint is complicated by the fact that the foot is set at a right angle to the leg. Bending movement at the ankle implies a diminution of the angle and is frequently termed flexion. On the other hand it results in the approximation of two morphologically dorsal surfaces and might, with an equal amount of justification, be termed extension. It will avoid confusion and misunderstanding if the self-explanatory terms *dorsi-flexion* and *plantar-flexion* are used in connexion with the movements at the ankle-joint.*

Abduction and adduction occur around a more or less anteroposterior axis, except in the case of the carpometacarpal joint of the thumb, where, for reasons already stated, these movements occur around a transverse axis. The terms imply movements from and to the median plane of the body, except in the cases of the digits, where the plane of reference is the median plane of the middle digit (in the hand) or the second digit (in the foot).

Circumduction is that form of motion which takes place between the head of a bone and its articular cavity, when the bone is made to circumscribe a conical space ; the base of the cone is described by the distal end of the bone, the apex is in the articular cavity ; this kind of motion is best seen in the shoulder- and hip-joints.

Rotation is a form of movement in which a bone moves round a longitudinal axis ; the axis of rotation may lie in a separate bone, as in the case of the pivot formed by the odontoid process of the axis, around which the atlas turns ; or a bone may rotate around its own longitudinal axis, as in the rotation of the humerus at the shoulder-joint ; or the axis of rotation may be not quite parallel to the long axis of the bone, as in the movement of the radius on the ulna during pronation and supination of the hand, where it is represented by a line connecting the centre of the head of the radius with the centre of the head of the ulna.

Accessory movements.—The movements which can be performed actively at any joint do not necessarily include all the movements which the structure of the joint would permit. Certain movements which cannot be performed voluntarily can nevertheless be produced when resistance is encountered to active movements (accessory movements, first type), e.g. it is only when some solid object, such as a cricket ball, is grasped in the hand, that the fingers can be rotated at the metacarpophalangeal joints. Other movements can be produced only passively (accessory movements, second type) and their widest range is obtained when the muscles acting on the joint are fully relaxed, e.g. when the

* Flexion has also been defined as the position assumed by the joints of the fœtus 'in utero.' Such a definition would imply that 'dorsi-flexion' of the ankle-joint is really 'flexion.' This view is supported by the physiological observation that in reflexes involving all the joints of the lower limb flexion at the hip- and knee-joints is always associated with 'dorsi-flexion' of the ankle-joint, and extension of the hip- and knee-joints with 'plantar-flexion' of the ankle-joint. The definitions based on morphological and physiological criteria are contradictory to each other and this emphasises the desirability for the use of the make-shift terms suggested in the text.

arm is partially abducted at the shoulder-joint, the humerus can be drawn away from the glenoid cavity. Such movements are commonly termed 'passive movements', but as all movements, whether active or not, can be performed passively when the muscles concerned are relaxed, the term *accessory movements* will be used to designate all movements which cannot be performed actively in the absence of resistance.

The possibility of accessory movements implies a certain amount of play between the articular surfaces of a joint, and this prevents undue strain or pressure on those surfaces when the joint is subjected to violent stresses. A considerable amount of play is permitted in the shoulder-joint, but none in the hip-joint. As a result damage of the articular surfaces is very much commoner in the latter, and the disease of osteoarthritis, which has its origin in trauma of an articular surface, is of much more frequent occurrence in the hip-joint than in the shoulder-joint.

Limitation of movements is effected by a number of different factors, of which the *tension of ligaments* is very important, as can be seen when attempts are made to produce hyperextension of the dissected knee or hip-joints. In life, however, the *tension of the muscles which are antagonistic to the movement* is equally important, if not more so, for it is open to doubt whether under normal conditions the tension of the antagonist muscles ever permits a ligament to be put fully on the stretch. The part played by muscles in limiting movement is well seen in flexion of the hip-joint. When this movement is performed with the knee extended, it is much more limited in range than when it is performed with the knee flexed. In the latter case flexion of the knee relaxes the hamstring muscles, and this permits the thigh to be flexed until it comes into contact with the anterior abdominal wall. The movement is then limited by *the approximation of the soft parts concerned*—a third factor which is present in connexion with some other movements, e.g. flexion of the elbow and knee.

In synovial joints, where the bones concerned are connected by ligaments and muscles only, the articular surfaces are in constant apposition in all positions of the joint throughout life. The maintenance of this apposition is assisted by atmospheric pressure and the force of cohesion, but these factors are merely subsidiary to the influence exerted by the muscles. The balance between the normal tonus of the different muscle groups which act on the joint is responsible for maintaining the articular surfaces in constant apposition. In this connexion it cannot be emphasised too strongly that the stability of any joint depends on the tonus of the muscles which act on it. The erect attitude is maintained by the balance between opposing muscle groups, and in the maintenance of this and other normal postures the ligaments play no part.

Nerve supply.—Movable joints are innervated by the nerves of supply to the muscles which act on them, and it is probable that this arrangement establishes local reflex arcs which tend to ensure stability. The part of the articular capsule which is rendered taut on the contraction of a given muscle or group of muscles is innervated by the nerve or nerves supplying their antagonists. For example, the inferior part of the articular capsule of the hip-joint, which is put on the stretch in abduction, is supplied by the obturator nerve. Tension of this part of the capsule produces a reflex contraction of the adductor muscles which, usually, is successful in preventing overstretching or tearing of the ligaments.

THE MANDIBULAR JOINT

The bony parts entering into the formation of the mandibular joint are: above, the articular eminence and the anterior portion of the articular fossa of the temporal bone; below, the head of the mandible. The *articular surfaces* are covered with a variety of white fibrocartilage in which the fibres predominate and the cartilage cells are few in number. An articular disc divides the joint into an upper and a lower cavity. The ligaments of the joint are the following:

Capsular.	Sphenomandibular.
Temporomandibular.	Stylomandibular.

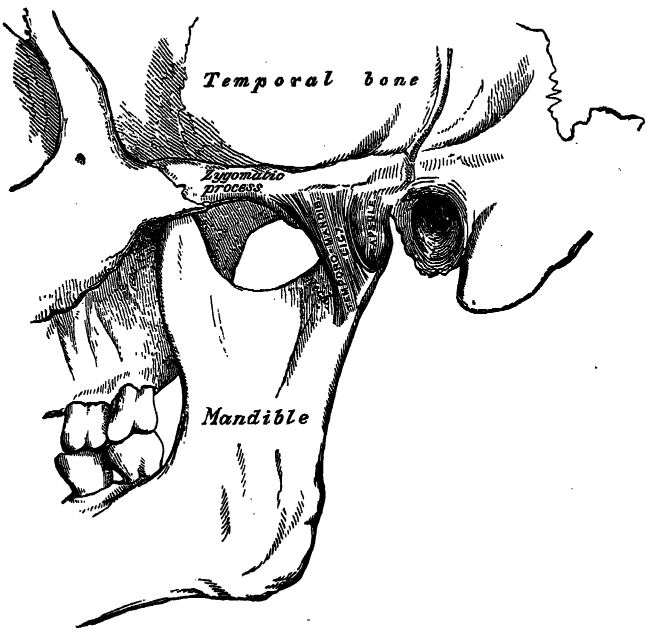
The capsular ligament is a thin, loose envelope, attached, above, to the

articular eminence in front; to the lips of the squamotympanic fissure behind; and between these two attachments, to the circumference of the articular fossa; below, to the neck of the mandible. The *synovial membrane* of the joint lines the capsular ligament and is continued over the upper and lower surfaces of the articular disc.

The **temporomandibular ligament** (fig. 504) is placed on the lateral side of the joint and is intimately related to the capsular ligament. It is attached, above, to the lateral surface of the zygomatic process of the temporal bone and to the tubercle on its root; below, to the lateral surface and posterior border of the neck of the mandible. It is broader above than below, and its fibres are directed obliquely downwards and backwards. The ligament is covered superficially by the parotid gland.

The **sphenomandibular ligament** (fig. 505) is placed on the medial side of the joint and is separated from the capsular ligament by a considerable interval. It is a flat, thin band which is attached above to the spine of the sphenoid bone, and, becoming broader as it descends, is fixed to the lingula of the mandibular

FIG. 504.—The left mandibular joint. Lateral aspect.



foramen. Its lateral surface is in relation, above, with the lateral pterygoid muscle and the auriculotemporal nerve; lower down, it is separated from the neck of the mandible by the maxillary (internal maxillary) vessels; still lower, the inferior dental (inferior alveolar) vessels and nerve and a lobule of the parotid gland lie between it and the ramus of the mandible. Its medial surface is in relation, below, with the medial pterygoid muscle, and, above, it is separated from the wall of the pharynx by an interval containing fat and some veins of the pharyngeal plexus. The upper attachment of the ligament is a secondary attachment,* and some of its fibres can be traced through the medial end of the petrotympanic fissure to the primary attachment, viz. the anterior process of the malleus. It represents a portion of the cephalic extremity of Meckel's cartilage (p. 99).

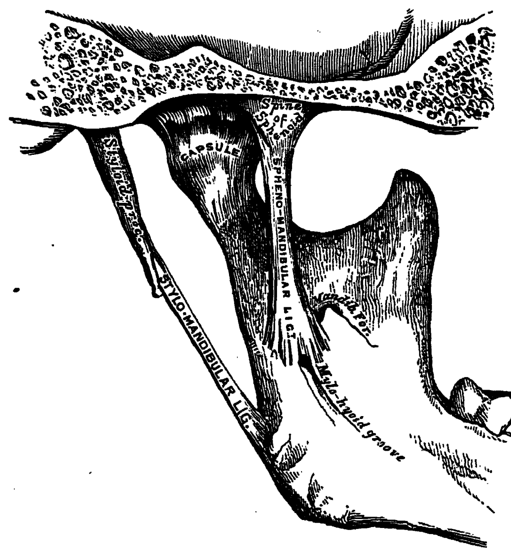
The **articular disc** (fig. 506) is a thin, oval plate consisting mainly of fibrous tissue; it is placed between the condyle of the mandible and the articular fossa, and divides the joint into two cavities. Its upper surface is concavoconvex from before backwards, to accommodate itself to the form of the articular fossa and the articular eminence. Its under surface, in contact with the head of the mandible, is concave. Its circumference is connected to the capsular ligament

* J. Cameron, *Journal of Anatomy and Physiology*, vol. xlix.

and, in front, to the tendon of the lateral pterygoid muscle. It is usually thickest a little behind its centre, where it occupies the deepest part of the articular fossa.

The **stylomandibular ligament** (fig. 505) is a specialised band of the deep cervical fascia (p. 537), which stretches from the apical part of the styloid process of the temporal bone to the angle and posterior border of the ramus of the mandible between the insertions of the masseter and medial pterygoid muscles. It separates the parotid from the submandibular (submaxillary) gland, and from its deep surface some fibres of the styloglossus take origin. Although classed among the ligaments of the mandibular joint, it can only be considered as accessory to it.

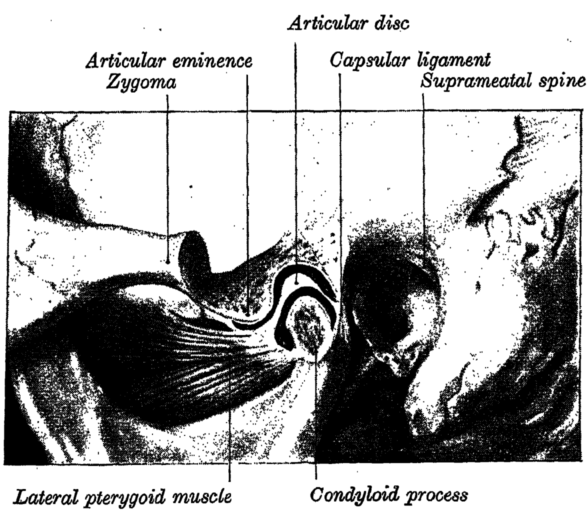
FIG. 505.—The left mandibular joint. Medial aspect.



The *nerves* of the mandibular joint are derived from the auriculotemporal and masseteric branches of the mandibular nerve; the *arteries*, from the superficial temporal branch of the external carotid artery, and from the maxillary artery (internal maxillary artery).

Movements.—The mandible may be depressed and elevated, or carried forwards and backwards; a slight amount of side-to-side movement is also permitted. When the mouth is opened the body of the mandible is depressed, and the head and articular disc are pulled forwards and downwards on to the

FIG. 506.—A sagittal section through the left mandibular joint.



articular eminence on each side; at the same time the head rotates on the articular disc round a more or less transverse axis. On closure of the mouth the reverse actions take place. When the mandible is carried horizontally forwards, as in protruding the lower incisor teeth in front of the upper, the disc and the head of the mandible glide forwards and downwards on the articular fossa and articular eminence on each side. The grinding or chewing movement is produced by the head, with its disc, gliding alternately forwards and backwards,

on one side, while on the other they move simultaneously in the opposite directions ; at the same time the head undergoes a vertical rotation on the disc. On one side the head advances and rotates, while on the other it recedes and rotates.

Muscles producing the movements :

Depression.—Digastric, Mylohyoid, Geniohyoid and Lateral Pterygoid (of both sides).
Elevation.—Masseter, Temporal and Medial Pterygoid (of both sides).
Protrusion.—Medial and Lateral Pterygoid (of both sides).
Retraction.—Temporal (posterior fibres—both sides).
Lateral movement.—Medial and Lateral Pterygoid (of one side).

Applied Anatomy.—The mandible can be dislocated in one direction only—viz. forwards. When the mouth is open, the head of the mandible is situated on the articular eminence, and any sudden violence, or even a sudden muscular spasm, as during a convulsive yawn, may displace it forwards into the infratemporal fossa. The displacement may be unilateral or bilateral. Reduction is accomplished by depressing the jaw with the thumbs placed on the last molar teeth, and at the same time elevating the chin. The downward pressure overcomes the spasm of the masseter, temporal, and pterygoid muscles, and elevation of the chin throws the head of the mandible backwards ; the above-mentioned muscles then draw the head back into its normal position.

The external auditory meatus and the tympanic cavity lie immediately behind the joint ; any force, therefore, applied to the mandible is liable to be attended with damage to these parts, or inflammation in the joint may extend to them. On the other hand inflammation of the tympanic cavity may involve the articulation and cause its destruction, thus leading to ankylosis of the joint.

THE JOINTS OF THE VERTEBRAL COLUMN

The vertebræ from the third cervical to the first sacral inclusive are articulated to one another by : (1) a series of cartilaginous joints between the vertebral bodies ; and (2) a series of synovial joints between the vertebral arches.

1. The Joints of the Vertebral Bodies

The cartilaginous joints between the bodies of the vertebræ allow of only slight movement between adjoining bones, but when this slight movement takes place in a number of consecutive joints the total range of movement is considerable. The vertebral bodies are united by anterior and posterior longitudinal ligaments, and by intervertebral discs of fibrocartilage.

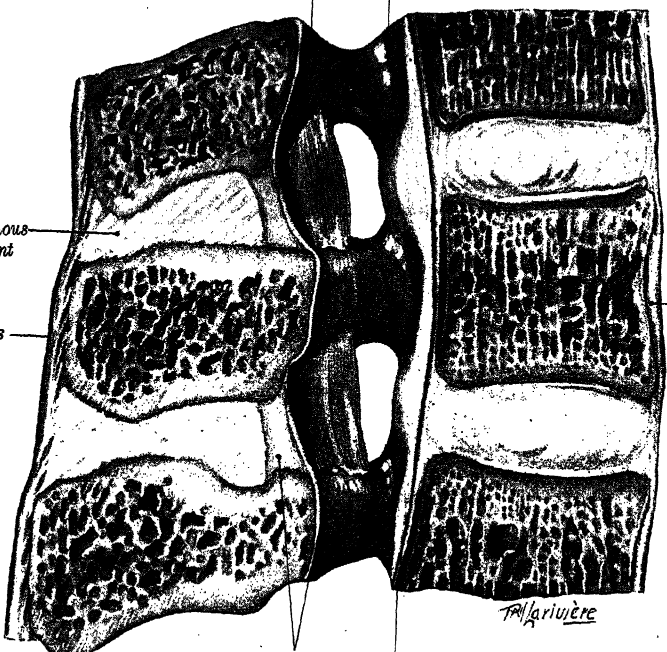
The **anterior longitudinal ligament** (fig. 507) is a strong band of fibres which extends along the anterior surfaces of the bodies of the vertebræ. It is broader below than above, thicker and narrower in the thoracic region than in the cervical and lumbar regions, and somewhat thicker and narrower opposite the bodies of the vertebræ than opposite the intervertebral discs. It is attached, above, to the basilar part of the occipital bone, from which it extends to the anterior tubercle of the atlas, then to the front of the body of the axis and is continued down as far as the upper part of the front of the sacrum. It consists of longitudinal fibres, which are firmly fixed to the intervertebral discs and to the margins of the vertebral bodies, but are loosely attached to the middle parts of the bodies. In the latter situation the ligament is thick and fills up the concavities on the anterior surfaces, and makes the front of the vertebral column more even. It is composed of several layers of fibres, of which the most superficial are the longest and extend between four or five vertebræ. The intermediate fibres extend between two or three vertebræ, while the deepest reach from one vertebra to the next. At the sides of the bodies the ligament consists of a few short fibres which connect adjacent vertebræ.

The **posterior longitudinal ligament** (figs. 507, 508) is situated within the vertebral canal on the posterior surfaces of the bodies of the vertebræ. Above, it is attached to the body of the axis, and is thence continued downwards to the sacrum ; its upper end is continuous with the membrana tectoria (p. 444). It

consists of smooth, glistening fibres, which are attached to the intervertebral discs and to the upper and lower margins of the vertebral bodies, but are separated from the middle parts of the bodies by the emerging basivertebral veins, and by veins which drain these into the anterior internal vertebral plexuses. In the cervical region the ligament is broad and of nearly uniform width, but in the thoracic and lumbar regions it presents a denticulated appearance, being narrow over the vertebral bodies and broad over the intervertebral discs. It consists of superficial layers occupying the interval between three or four vertebræ, and deeper layers which extend between adjacent vertebræ.

The intervertebral discs (figs. 507, 508) are interposed between the adjacent surfaces of the bodies of the vertebræ, from the axis to the sacrum, and form

Fig. 507.—A median sagittal section through a portion of the lumbar region of the vertebral column.

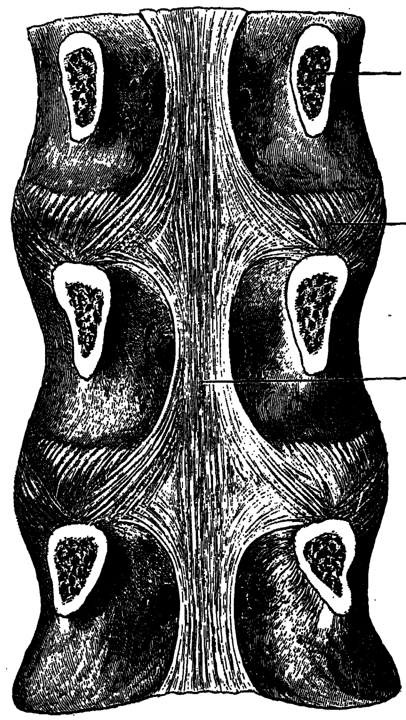


the chief bonds of connexion between the vertebræ. Their shape corresponds with that of the bodies between which they are placed. Their thickness varies in different regions of the column, and in different parts of the same disc; they are thicker in front than behind in the cervical and lumbar regions, and thus contribute to the anterior convexities of these parts of the column; while they are of nearly uniform thickness in the thoracic region, the anterior concavity of this part of the column being almost entirely due to the shape of the vertebral bodies. They are adherent, by their surfaces, to thin layers of hyaline cartilage which cover the upper and under surfaces of the bodies of the vertebræ. The intervertebral discs are closely connected to the anterior and posterior longitudinal ligaments; in the thoracic region they are joined laterally, by means of the intra-articular ligaments, to the heads of those ribs which articulate with two vertebræ. The intervertebral discs constitute about one-fourth of the length of the vertebral column, exclusive of the first two vertebræ; but this amount is not equally distributed between the various bones, the cervical and lumbar portions having, in proportion to their length, a much greater amount

than the thoracic region, with the result that these parts possess greater pliancy and freedom of movement.

Structure of the intervertebral discs.—Each is composed, at its circumference, of laminæ of fibrous tissue and fibrocartilage, forming the *annulus fibrosus* ; and, at its centre, of a soft, pulpy, highly elastic substance, of a yellowish colour, which projects considerably above the surrounding level when the disc is divided horizontally. This pulpy substance (*nucleus pulposus*), especially well developed in the lumbar region, contains the remains of the notochord. The laminæ of the annulus fibrosus are arranged concentrically ; the peripheral consist of ordinary fibrous tissue, the others of white fibrocartilage. The laminæ are not quite vertical in their direction, those near the circumference being curved outwards

FIG. 508.—The posterior longitudinal ligament of the vertebræ, in the lumbar region.



and closely approximated ; while those nearest the centre curve in the opposite direction, and are somewhat more widely separated. The fibres composing the laminæ are directed, for the most part, obliquely from above downwards, the fibres of adjacent laminæ cross one another, like the limbs of the letter X. This laminar arrangement exists in about the outer half of each disc. The nucleus pulposus consists of a fine fibrous matrix, containing angular cells united to form a reticular structure.

In the cervical region the cartilaginous joints between the bodies of the vertebræ are complicated occasionally by the presence of a small synovial cavity on each side between the bevelled lateral part of the under surface of the body and the lipped lateral margin of the upper surface of the body below. It is this little joint which is enlarged to form the principal joint in the case of the articulation between the atlas and the axis.

2. The Joints of the Vertebral Arches

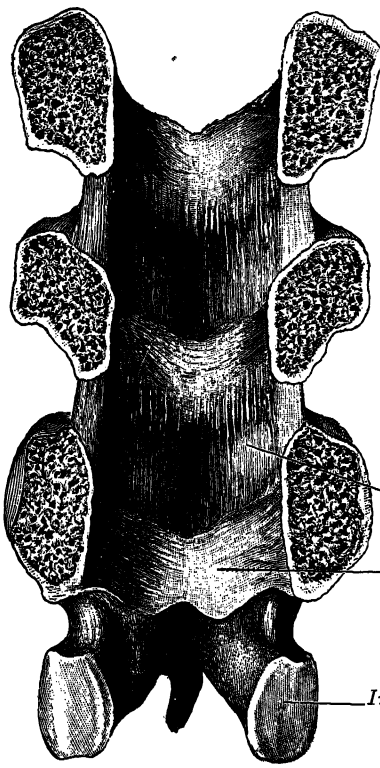
The joints between the articular processes of the vertebræ belong to the plane variety and are enveloped by articular capsules ; the laminæ, spines and transverse processes are connected by the following ligaments :

Ligamenta flava. Ligamentum nuchæ.
Supraspinous. Interspinous.
Intertransverse.

The **articular capsules** are thin and loose, and are attached just beyond the margins of the articular facets of adjacent articular processes ; they are longer and looser in the cervical than in the thoracic and lumbar regions.

The **ligamenta flava** (figs. 507, 509) connect the laminæ of adjacent vertebræ, and are best seen from the interior of the vertebral canal. Their attachments extend from the articular capsules to the regions where the laminæ fuse to form the spine ; here their posterior margins come into contact and are to a certain extent united, small intervals being left for the passage of vessels. The ligamenta flava consist of yellow elastic tissue, the fibres of which, almost perpendicular in direction, are attached to the lower part of the anterior surface of the

FIG. 509.—The ligamenta flava of the lumbar region. Anterior aspect.



lamina above, and to the posterior surface and upper margin of the lamina below. The ligaments are thin, but broad and long in the cervical region ; they are thicker in the thoracic region, and thickest in the lumbar region. They prevent excessive flexion and, by virtue of their elasticity, they help to control the movement, graduating it so that its limit is not reached abruptly. In this way they serve to guard against injury of the discs. They also assist in restoring the vertebral column to the erect attitude, after it has been flexed.

The **supraspinous ligament** (fig. 507) is a strong fibrous cord which connects together the apices of the spines from the seventh cervical vertebra to the sacrum ; fibrocartilage is developed in the ligament at its points of attachment to the tips of the spines. It is thicker and broader in the lumbar region than in the thoracic, and intimately blended in both situations with the neighbouring fascia. The most superficial fibres of this ligament extend over three or four vertebræ ; those more deeply seated pass between two or three vertebræ ; while the deepest connect the spines of neighbouring vertebræ. In front it is continuous with the interspinous ligaments. Between the spine of the seventh cervical vertebra and the external occipital protuberance its place is taken by the ligamentum nuchæ.

The **ligamentum nuchæ** is a fibrous membrane, which, in the neck, is homologous with the supraspinous ligament of the thoracic and lumbar vertebræ. It

extends from the external protuberance and external occipital crest to the spine of the seventh cervical vertebra. From its anterior border a fibrous lamina is given off, which is attached to the posterior tubercle of the atlas and to the spines of the cervical vertebræ, and forms a septum between the muscles of the two sides of the neck. In man it is the representative of an important elastic ligament which, in some of the lower animals, controls the movement of flexion of the head, functioning in the same way as the ligamenta flava in man.

The **interspinous ligaments** (fig. 507), thin and membranous, connect adjoining spines, and their attachments extend from the root to the apex of each process. They meet the ligamenta flava in front and the supraspinous ligament behind. They are narrow and elongated in the thoracic region ; broader, thicker, and quadrilateral in form in the lumbar region ; and only slightly developed in the neck.

The **intertransverse ligaments** are interposed between the transverse processes. In the cervical region they consist of a few, irregular, scattered fibres in the thoracic region they are rounded cords intimately connected with the deep muscles of the back ; in the lumbar region they are thin and membranous.

Movements of the vertebral column.—The range of movement possible between any two adjoining vertebræ is very restricted, and this limitation is to be attributed to the presence of the intervertebral disc connecting the vertebral bodies. The greater thickness of the discs in the cervical and lumbar regions as compared with the thoracic region is associated with the greater individual ranges of movement occurring in those regions. But, although the range of movement between any two adjoining vertebræ is small, the summation of these movements gives a relatively wide range of movement to the vertebral column as a whole.

The movements permitted in the vertebral column are : flexion or forward bending, extension or backward bending, bending to one or other side (usually termed lateral flexion), rotation and circumduction.

In *flexion* the anterior longitudinal ligament is relaxed and the anterior parts of the intervertebral discs are compressed ; while at the limit of the movement the posterior longitudinal ligament, the ligamenta flava, and the interspinous and supraspinous ligaments are stretched, as well as the posterior fibres of the intervertebral discs. The interspaces between the laminæ are widened, and the inferior articular processes glide upwards upon the superior articular processes of the subjacent vertebræ. It should be remembered, however, that tension of the extensor muscles of the back is the most important factor in limiting the movement. Flexion is most extensive in the cervical region.

In *extension* an exactly opposite disposition of the parts takes place.* This movement is limited by the tension of the anterior longitudinal ligament, and by the approximation of the spines. It is free in the cervical and lumbar regions, but is restricted in the thoracic region.

In *lateral flexion* the sides of the intervertebral discs are compressed, the extent of motion being limited by the resistance offered by the tension of the antagonist muscles and the surrounding ligaments. Lateral movements may take place in any part of the column, but are freest in the cervical and lumbar regions.

Circumduction is limited, and is merely a succession of the preceding movements.

Rotation is produced by the twisting of the vertebræ on the intervertebral discs ; this, although only slight between any two vertebræ, allows of a considerable extent of movement when it takes place in the whole length of the column, the front of the upper part of the column being turned to one or other side. This movement occurs to a slight extent in the cervical region, is freer in the upper part of the thoracic region, and almost negligible in the lumbar region.

* P. Wiles (*Proc. of the Roy. Soc. of Medicine*, vol. xxviii. 1935) is of opinion that in full extension the axis of movement lies just behind the articular processes and that it moves forwards as the column is straightened until, in full flexion, it passes through, approximately, the middle of the vertebral body.

The extent and variety of the movements are influenced by the shape and direction of the articular facets. In the *cervical* region the upward inclination of the superior articular facets allows of free flexion and extension. Extension can usually be carried farther than flexion ; at the upper end of the region it is checked by the locking of the posterior edges of the superior atlantal facets in the condylar fossæ of the occipital bone ; at the lower end it is limited by a mechanism whereby the inferior articular processes of the seventh cervical vertebra slip into grooves behind and below the superior articular processes of the first thoracic vertebra. Flexion is arrested just beyond the point where the cervical convexity is straightened ; the movement is checked by the apposition of the projecting lower lips of the bodies of the vertebræ with the shelving surfaces on the bodies of the subjacent vertebræ. Lateral flexion and rotation in the cervical region are always combined ; the upward and medial inclinations of the superior articular facets impart a rotatory movement during attempts at lateral flexion. In the *thoracic* region, notably in its upper part, all the movements are limited in order to reduce interference with respiration to a minimum. The almost complete absence of an upward inclination of the superior articular facets prohibits any marked flexion, while extension is checked by the contact of the inferior articular margins with the laminæ, and the contact of the spines with one another. Rotation is free in the thoracic region : the superior articular processes are segments of a cylinder whose axis passes through the vertebral bodies. The direction of the articular facets would allow of free lateral flexion, but this movement is considerably limited in the upper part of the region by the resistance of the ribs and sternum. In the *lumbar* region extension is free and wider in range than flexion. The inferior articular facets are not in close apposition with the superior facets of the subjacent vertebræ, and on this account a considerable amount of lateral flexion is permitted. The amount of rotation possible is almost negligible, owing to the arrangement of the articular processes.

Muscles producing the movements.—The vertebral column may be moved either by muscles attached to it and acting directly on it, or by muscles attached to other bones and acting indirectly on the column.

The principal muscles actively concerned in producing (1) *flexion* are the longus cervicis (longus colli), the scaleni, the sternomastoid, the rectus abdominis and the gluteus maximus (which, in the erect attitude, acts on the lumbar region through the hip-bone), of both sides in each case ; (2) *extension*, the sacrospinalis, the splenius capitis and the semispinalis capitis, of both sides in each case ; (3) *lateral flexion*, the longissimus and iliocostocervicalis portions of the sacrospinalis, the oblique muscles of the abdominal wall, and the muscles concerned in flexion, of one side only in each case ; and (4) *rotation*, the rotatores, the multifidus and the splenius cervicis.

3. The Sacrococcygeal Joint

This articulation is a cartilaginous joint, between the apex of the sacrum and the base of the coccyx, the bones being united by anterior, posterior and lateral sacrococcygeal ligaments, and by a disc of fibrocartilage.

The **anterior sacrococcygeal ligament** (fig. 540) consists of a few irregular fibres which descend from the anterior surface of the sacrum to the front of the coccyx.

The **superficial posterior sacrococcygeal ligament** is a flat band which arises from the margin of the sacral hiatus, and descends to be inserted into the posterior surface of the coccyx. This ligament completes the lower part of the sacral canal.

The **deep posterior sacrococcygeal ligament** extends from the back of the fifth sacral vertebra to the back of the coccyx.

The *intercornual ligaments* connect the cornua of the sacrum and coccyx on each side.

A **lateral sacrococcygeal ligament** exists on each side and connects the transverse process of the coccyx to the inferior lateral angle of the sacrum ; it completes the foramen for the fifth sacral nerve.

A thin disc of fibrocartilage is interposed between the contiguous surfaces of the sacrum and coccyx ; it is somewhat thicker in front and behind than at the sides. Occasionally the coccyx is freely movable on the sacrum ; in such cases an articular capsule lined with synovial membrane is present.

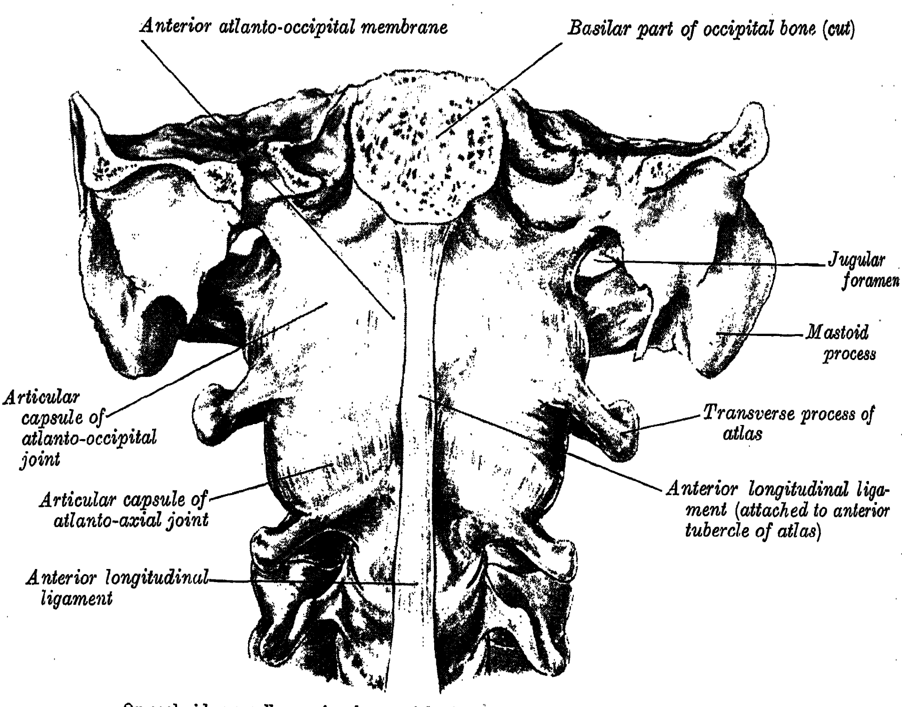
In the young subject the different segments of the coccyx are connected together by the extension downwards of the anterior and posterior sacro-coccygeal ligaments, thin annular discs of fibrocartilage being interposed between the segments. In the adult male, all the pieces become ossified together at a comparatively early period ; but in the female, this does not commonly occur until a later period of life. At a more advanced age the joint between the sacrum and coccyx is obliterated.

Backward and forward movements take place between the sacrum and coccyx ; their extent increases during pregnancy.

4. The Atlanto-Axial Joints

The articulation of the atlas with the axis is of a complicated nature and comprises three synovial joints. Of these one is placed on each side between the inferior facet of the lateral mass of the atlas and the superior facet of the axis: the other is median in position and is placed between the odontoid process (dens) and the anterior arch of the atlas.

Fig. 510.—The atlanto-occipital and atlanto-axial joints. Anterior aspect.



On each side a small, occasional, synovial joint is shown between the lateral part of the upper surface of the body of the third cervical vertebra and the bevelled, inferior surface of the body of the axis. The joint cavities have been opened.

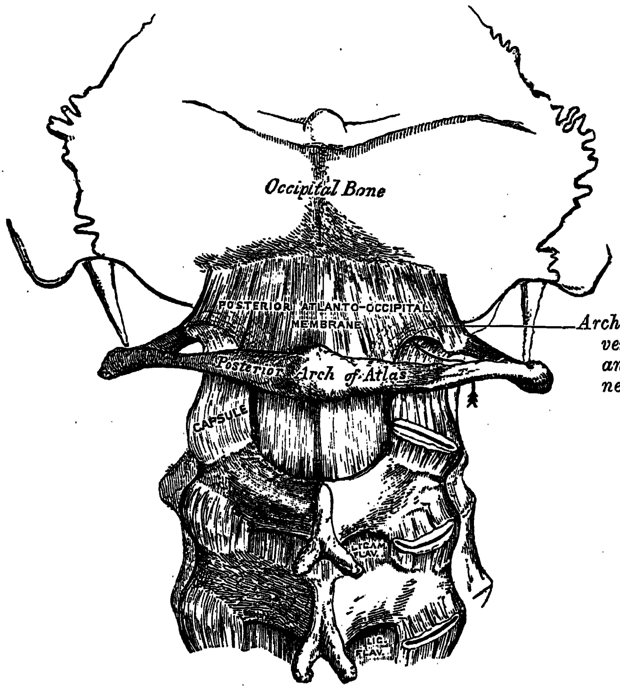
The lateral atlanto-axial joints are plane joints, but the *articular surfaces* involved are both slightly convex in their long axes.

The *capsular ligaments* are thin and loose ; they surround the joints and are lined with synovial membrane. Each is strengthened at its posterior and medial part by an *accessory ligament*, which is attached below to the body of the axis near the base of the odontoid process, and above to the lateral mass of the atlas near the transverse ligament.

In front the two vertebræ are connected by a continuation of the anterior longitudinal ligament (fig. 510). In this position it is a strong membrane, fixed

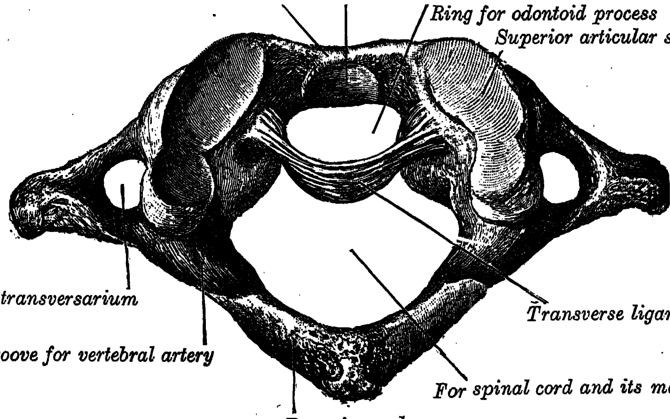
above to the lower border of the anterior arch of the atlas, and below to the front of the body of the axis. It is strengthened in the median plane by a rounded cord which connects the tubercle on the anterior arch of the atlas to the body of the axis.

FIG. 511.—The posterior atlanto-occipital membrane.



Behind, the atlas and axis are joined by a broad, thin membrane (fig. 511) attached above to the lower border of the posterior arch of the atlas, below to the upper edges of the laminæ of the axis ; it is in series with the ligamenta flava and is pierced near its lateral extremity by the second cervical nerve.

FIG. 512.—The atlas vertebra, with the transverse ligament.



The median atlanto-axial joint is a pivot-joint between the odontoid process of the axis and the ring formed by the anterior arch and the transverse ligament of the atlas ; the *articular surfaces* are reciprocally curved.

FIG. 513.—The atlanto-occipital and atlanto-axial joints, shown from behind after removal of the posterior part of the occipital bone and the laminæ of the upper cervical vertebræ. The atlanto-occipital joint-cavities have been opened.

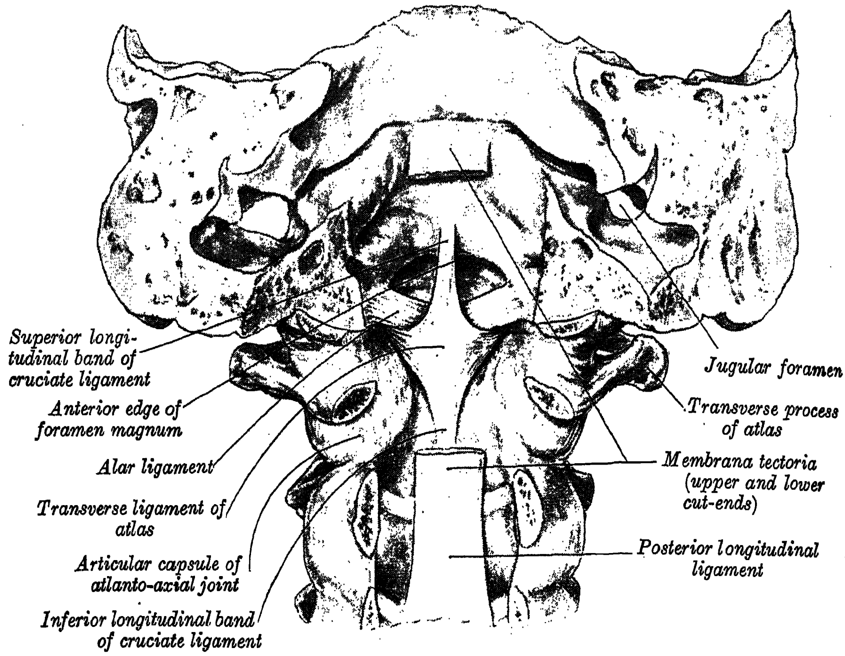
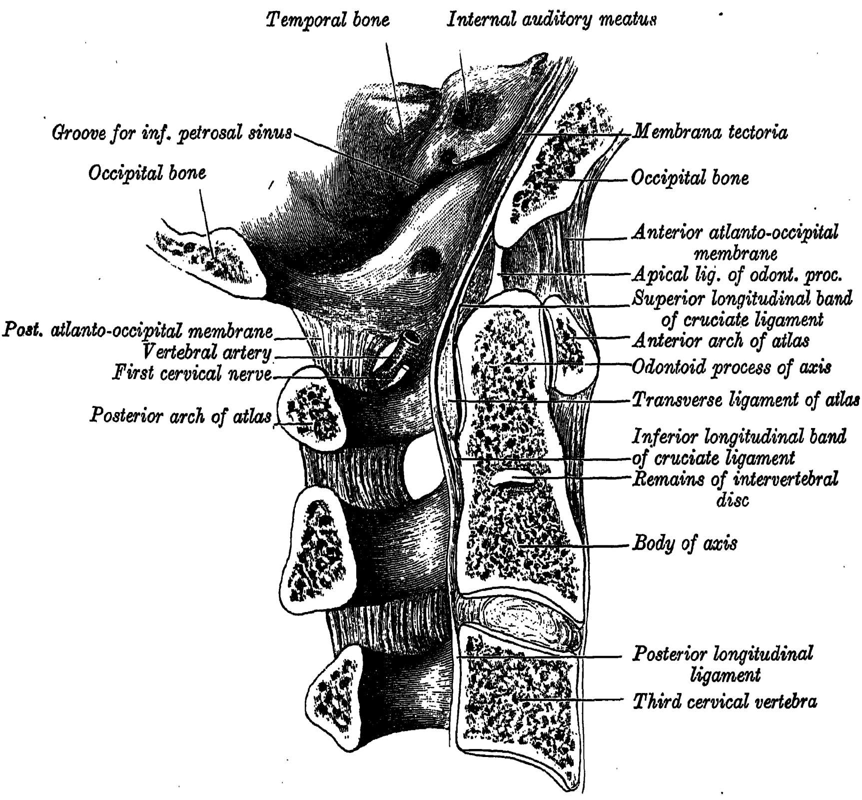


FIG. 514.—A median sagittal section through the occipital bone and first three cervical vertebræ.



The *capsular ligament* is weak and loose and is lined with synovial membrane. A second synovial cavity is present and lies between the transverse ligament of the atlas and the posterior surface of the odontoid process : it is often continuous with the joint-cavity of one or other of the atlanto-occipital joints.

The **transverse ligament of the atlas** (figs. 512-514) is a thick, strong band which arches across the ring of the atlas and retains the odontoid process of the axis in contact with the anterior arch. It is concave in front, convex behind, broader in the middle than at the ends, and firmly attached on each side to a small tubercle on the medial surface of the lateral mass of the atlas. The median part of the anterior surface is covered by a thin layer of articular cartilage. As the ligament crosses the odontoid process, a small longitudinal band is prolonged upwards, and another downwards, from its superficial or posterior fibres. The upper band is attached to the upper surface of the basilar part of the occipital bone between the apical ligament of the odontoid process and the membrana tectoria ; the lower band is attached to the posterior surface of the body of the axis ; hence the whole ligament is named the *cruciate ligament of the atlas*. The transverse ligament divides the ring of the atlas into two unequal parts (fig. 512) : of these, the posterior and larger surrounds the spinal cord and its membranes and the spinal roots of the accessory nerves ; the anterior and smaller contains the odontoid process. The neck of the process is constricted where it is embraced posteriorly by the transverse ligament, so that this ligament suffices to retain the odontoid process in position after all the others have been divided.

Movements.—Movement must occur at all three joints at the same time, and it allows the rotation of the atlas (and with it the skull) upon the axis, the extent of rotation being limited by the alar ligaments (p. 444).

The opposed articular facets of the atlas and axis are both slightly convex in their long axes, as already stated. When, therefore, the upper facet glides forwards on the lower it also descends. The stretching of the fibres of the capsular ligament that would result from this forward movement is diminished owing to the contemporaneous descent of their upper attachments, and in this way excessive laxity of the capsule is obviated.

Muscles producing the movements.—The principal muscles by which these movements are produced are the obliquus capitis inferior, the rectus capitis posterior major and the splenius capitis of one side, acting with the sterno-mastoid muscle of the other side.

THE JOINTS OF THE VERTEBRAL COLUMN WITH THE CRANIUM

The articulation of the vertebral column with the cranium involves not only a pair of atlanto-occipital joints and their ligaments, but also a number of ligaments which connect the axis with the occipital bone.

1. The Atlanto-Occipital Joints

On each side the atlanto-occipital joint is placed between the superior articular facet of the lateral mass of the atlas and the condyle of the occipital bone : it is condyloid in type. The *articular surfaces* are reciprocally curved, but do not exactly correspond, as the atlantal facet may be constricted or occasionally subdivided into two, an arrangement which facilitates the lubrication of the joint. The ligaments connecting the bones are :

Two capsular.	Anterior and posterior atlanto-occipital membranes.

The **capsular ligaments** surround the condyles of the occipital bone and the superior articular facets of the atlas : they are thin and loose and are lined with synovial membrane. Their lateral portions are directed obliquely upwards and medially, and are reinforced by bundles of fibres, which are attached above to the jugular processes of the occipital bone, and below to the bases of the transverse processes of the atlas.

The atlanto-occipital joints frequently communicate with the joint between the odontoid process and the transverse ligament of the atlas.

The **anterior atlanto-occipital membrane** (fig. 510) is broad, and composed of densely woven fibres which pass between the anterior margin of the foramen magnum above, and the upper border of the anterior arch of the atlas below; laterally it is continuous with the capsular ligaments; in front, it is strengthened in the median plane by the continuation of the anterior longitudinal ligament, a strong, rounded cord, which connects the basilar part of the occipital bone to the tubercle on the anterior arch of the atlas (fig. 510).

The **posterior atlanto-occipital membrane** (fig. 511), broad but thin, is connected above to the posterior margin of the foramen magnum; below, to the upper border of the posterior arch of the atlas. On each side it arches over the groove for the vertebral artery, and with this groove bounds an opening for the entrance of the artery and the exit of the first cervical nerve. The free border of the membrane, arching over the artery and nerve, is sometimes ossified.

Movements.—The long axes of the two joints are set obliquely and run from behind forwards and medially. As a result of this obliquity and of the curvature of the occipital condyle, the corresponding articular surfaces of the two sides are in reality portions of the surface of an ellipsoid, the long axis of which is set transversely. The two joints therefore act as one, and movement may occur around transverse and anteroposterior axes, but not round a vertical axis. The movements permitted therefore are (*a*) flexion and extension, which give rise to the ordinary forward and backward nodding of the head, and (*b*) slight lateral motion to one or other side.

Muscles producing the movements:

Flexion.—Longus capitis, Rectus capitis anterior, and Sternomastoid.
Extension.—Recti capitis posteriores major et minor, Obliquus superior, Semispinalis capitis, Splenius capitis, and Trapezius (upper fibres).
Lateral flexion.—Rectus capitis lateralis, Semispinalis capitis, Splenius capitis, Sternomastoid and Trapezius (upper fibres).

2. The Ligaments connecting the Axis with the Occipital Bone

Membrana tectoria. Two alar. Apical ligament.

The **membrana tectoria** (figs. 513, 514) is situated within the vertebral canal. It is a broad, strong band, which covers the odontoid process and its ligaments and appears to be a prolongation upwards of the posterior longitudinal ligament of the vertebral column. It is fixed below to the posterior surface of the body of the axis, and, expanding as it ascends, is attached above to the upper surface of the basilar part of the occipital bone, in front of the foramen magnum, blending with the cranial dura mater. It covers the posterior aspect of the cruciate ligament of the atlas.

The **alar ligaments of the odontoid process** (fig. 513) are two strong, rounded cords, which arise one on each side of the upper part of the odontoid process, and passing obliquely upwards and laterally, are inserted into rough impressions on the medial sides of the condyles of the occipital bone. The alar ligaments are relaxed on extension of the head but become taut on flexion and help to limit the movement. They are so disposed that they would render free rotation of the head impossible, were it not for the fact that the movement of rotation is accompanied by a slight descent of the atlas (p. 443). This descent causes sufficient relaxation of the alar ligaments to compensate for the tension brought about by rotation. Rotation to the right is eventually checked by the tension of those fibres of the right alar ligament which are attached to the odontoid process in front of the axis of movement, and by tension of those fibres of the left alar ligament which are attached to the process behind the axis of movement. Rotation to the left is checked by the opposite fibres on each side.

The **apical ligament of the odontoid process** (fig. 514), which extends from the tip of the process to the anterior margin of the foramen magnum, lies between

the alar ligaments, being intimately blended with the deep portion of the anterior atlanto-occipital membrane and with the upper longitudinal band of the cruciate ligament of the atlas. It is regarded as a rudimentary intervertebral disc, and may contain traces of the notochord in its substance.

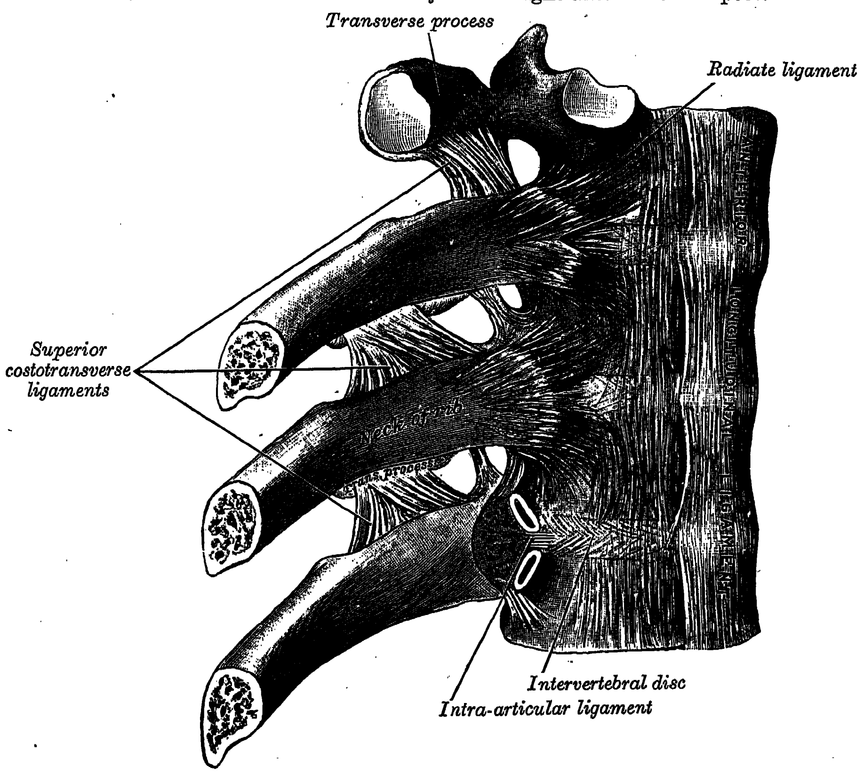
It must be remembered that, in addition to the ligaments which unite the atlas and axis to the skull, the ligamentum nuchæ (p. 437) connects the cervical vertebræ with the cranium.

Applied Anatomy.—Dislocation of the atlas from the axis, with rupture of the transverse ligament of the atlas and consequent injury to the spinal cord, is the mode in which death is produced in many cases of execution by hanging. Hanging may however produce a fracture through the axis, or a separation through the disc between the axis and the third cervical vertebra. Following infective conditions of the pharynx or in its vicinity, the cruciate ligament may become softened and occasionally a pathological dislocation of the atlas on the axis may result.

THE COSTOVERTEBRAL JOINTS

The articulations of the ribs with the vertebral column may be divided into two sets, one connecting the heads of the ribs with the bodies of the vertebræ, the other uniting the necks and tubercles of the ribs with the transverse processes.

FIG. 515.—The costovertebral joints. Right anterolateral aspect.



1. The Joints of the Heads of the Ribs (fig. 515)

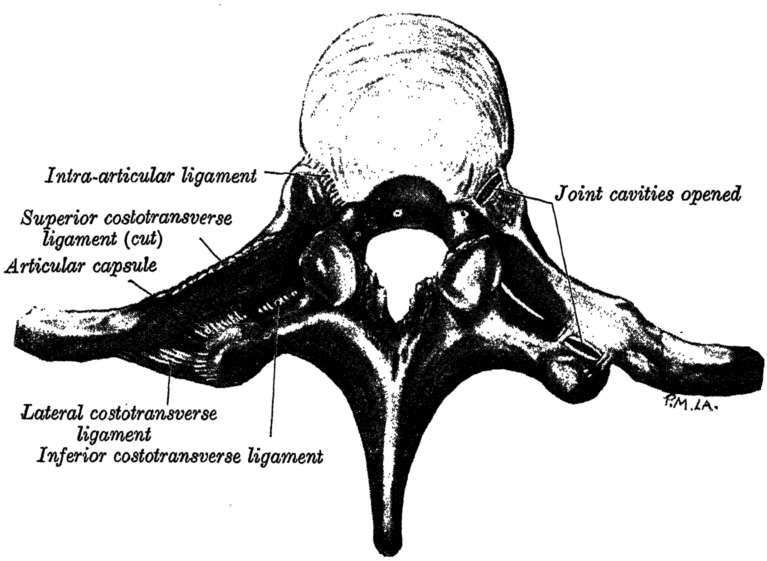
These articulations constitute a series of plane joints. They are formed by the articulation of the heads of the typical ribs with the facets on the contiguous margins of the bodies of the thoracic vertebræ, and with the intervertebral discs between them. The first, tenth, eleventh, and twelfth ribs each articulate with a single vertebra; in each of the other joints, an intra-articular ligament divides the joint cavity into two distinct parts. The ligaments of the joints are:

Capsular. Radiate.
Intra-articular.

The **capsular ligaments** connect the heads of the ribs with the circumferences of the articular cavities formed by the intervertebral discs and the adjacent vertebræ. Some of their upper fibres pass through the intervertebral foramen to the back of the intervertebral disc, while the posterior fibres are continuous with the inferior costotransverse ligament (ligament of the neck of the rib).

The **radiate ligament** connects the anterior part of the head of each rib with the sides of the bodies of two vertebræ, and the intervertebral disc between them. It is attached to the anterior part of the head of the rib, just beyond the articular surface. The superior fibres ascend and are connected with the body of the vertebra above ; the inferior fibres descend to the body of the vertebra below ; the middle fibres, the smallest and least distinct, are horizontal and attached to the intervertebral disc.

FIG. 516.—The costovertebral joints, viewed from above.



In the articulation of the first rib, the radiate ligament is attached to the body of the last cervical vertebra, as well as to that of the first thoracic. In the articulations of the tenth, eleventh and twelfth ribs, each of which articulates with a single vertebra, the radiate ligament is connected to the vertebra with which the rib articulates, and also to the vertebra immediately above it.

The **intra-articular ligament** is situated in the interior of the joint. It consists of a short band of fibres, flattened from above downwards, attached laterally to the crest separating the two articular facets on the head of the rib, and medially to the intervertebral disc ; it divides the joint into two cavities and its upper and lower surfaces are covered with synovial membrane. In the joints of the first, tenth, eleventh and twelfth ribs, intra-articular ligaments do not exist ; consequently, there is but one cavity in each of these articulations. The intra-articular ligament is the homologue of the *ligamentum conjugale*, which is present in some mammals and unites the heads of opposite ribs across the back of the intervertebral disc.

2. THE COSTOTRANSVERSE JOINTS (fig. 516)

The articular portion of the tubercle of a rib forms a plane joint with the transverse process of the vertebra to which it corresponds numerically. In the eleventh and twelfth ribs this articulation is wanting. In the upper six (or five) joints the *articular surfaces* are reciprocally curved, but in the lower joints the surfaces are flattened (p. 214).

The ligaments of the joints are:

Capsular.	Inferior costotransverse.
Superior costotransverse.	Lateral costotransverse.

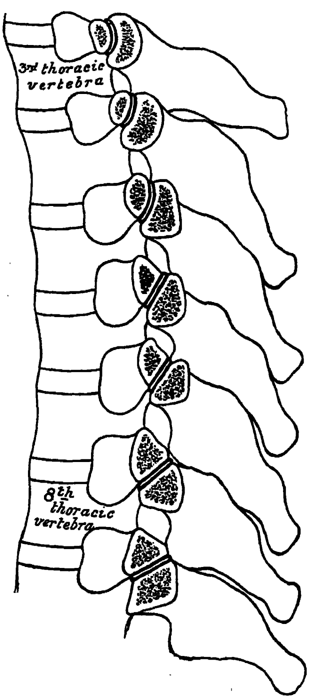
The **capsular ligament** is a thin membrane attached to the circumference of the articular surfaces, and lined with synovial membrane.

The **superior (anterior) costotransverse ligament** comprises an anterior and a posterior layer. The anterior fibres are attached below to the crest of the neck of the rib and pass upwards and laterally to the lower border of the transverse process immediately above. Laterally they are continuous with the fibres of the posterior intercostal membrane, and they are crossed anteriorly by the corresponding intercostal vessels and nerve. The posterior fibres are attached to the posterior surface of the neck of the rib and run upwards and medially behind the anterior fibres to reach the transverse process immediately above. Laterally they are intimately related to the external intercostal muscle.

The first rib has no superior costotransverse ligament. The neck of the twelfth rib is connected to the base of the transverse process of the first lumbar vertebra by a band of fibres, named the *lumbocostal ligament*; it is in series with the superior costotransverse ligaments.

An additional ligamentous band is usually present, although it is somewhat variable in its disposition. It is attached to a depression above and medial to the tubercle of the rib and, passing medial to the intertransverse ligament, it reaches the back of the inferior articular process, often sending a few fibres upwards to the base of the transverse process. Through the interval between this band and the medial border of the superior costotransverse ligament, the posterior primary ramus of the corresponding thoracic nerve runs backwards with its accompanying vessels.

FIG. 517.—A section through the costotransverse joints from the third to the ninth inclusive. Contrast the concave facets on the upper with the flattened facets on the lower transverse processes.



The **inferior costotransverse ligament** (ligament of the neck of the rib) consists of short but strong fibres, connecting the rough surface on the back of the neck of the rib with the anterior surface of the adjacent transverse process. A rudimentary ligament may be present at the eleventh and twelfth ribs.

The **lateral costotransverse ligament** (ligament of the tubercle of the rib) is a short, thick, strong fasciculus, which passes obliquely from the apex of the transverse process to the rough non-articular portion of the tubercle of the rib. The ligaments attached to the upper ribs ascend from the transverse processes; they are shorter and more oblique than those attached to the lower ribs, which descend slightly.

Movements.—The heads of the ribs are so closely connected to the bodies of the vertebræ by the radiate and intra-articular ligaments that only slight gliding movements of the articular surfaces on one another can take place. Similarly, the strong ligaments binding the necks and tubercles of the ribs to the transverse processes limit the movements of the costotransverse joints to slight gliding, the nature of which is determined by the shape and direction of the articular surfaces (fig. 517). The articular surfaces on the tubercles of the upper six ribs are oval in shape and convex from above downwards; they fit into corresponding concavities on the anterior surfaces of the transverse processes, so that upward and downward movements of the tubercles are associated with rotation of the rib-neck on its long axis. On the seventh, eighth, ninth and tenth ribs the articular surfaces on the tubercles are flat, and face obliquely downwards, medially and backwards. The surfaces with

which they articulate are placed on the upper aspects of the transverse processes ; when, therefore, the tubercles are drawn up they are at the same time carried backwards and medially. The joints of the heads of the ribs and the costotransverse joints move simultaneously and in the same directions, the total effect being that the neck of the rib moves as if on a single joint, of which the two articulations form the ends. In the upper six ribs the neck of the rib moves but slightly upwards and downwards ; its chief movement is one of rotation round its own long axis, rotation downwards of the front of the neck of the rib being associated with depression, rotation upwards with elevation of the anterior end of the rib and its costal cartilage. In the seventh, eighth, ninth and tenth ribs the neck of the rib moves upwards, backwards and medially, or downwards, forwards and laterally, with resultant increase or diminution of the infrasternal angle ; very slight rotation accompanies these movements.

Muscles producing the movements.—These are discussed with the mechanism of respiration (p. 558).

THE STERNOCOSTAL JOINTS (fig. 518)

The cartilages of the true ribs, with the exception of the first, articulate with the sternum by synovial joints. The cartilage of the first rib is directly united with the sternum, and the joint between this rib and the sternum is a primary cartilaginous joint.

The ligaments of the synovial joints are :

Capsular.	Intra-articular.
Sternocostal.	Costoxiphoid.

The **capsular ligaments** surround the joints between the sternum and the cartilages of the ribs from the second to the seventh inclusive. They are very thin, intimately blended with the sternocostal ligaments, and strengthened at the upper and lower parts of the articulations by a few fibres which connect the cartilages to the side of the sternum.

The **sternocostal ligaments** are broad, thin, membranous bands which radiate from the front and back of the sternal ends of the cartilages of the true ribs to the anterior and posterior surfaces of the sternum. Their superficial fibres intermingle with the fibres of the ligaments above and below them, with those of the opposite side, and on the front of the sternum with the tendinous fibres of origin of the pectoralis major, forming a thick fibrous membrane which envelops the bone, and is more distinct at its lower part than at its upper part.

The **intra-articular ligaments** are constantly present only between the second costal cartilages and the sternum. The cartilage of the *second rib* is connected with the sternum by means of an intra-articular ligament, attached laterally to the cartilage of the rib, and medially to the fibrocartilage which unites the manubrium and body of the sternum. Occasionally the cartilage of the *third rib* is connected with the first and second pieces of the body of the sternum by an intra-articular ligament. Still more rarely, similar ligaments are found in the other four joints of the series. In the lower two an intra-articular ligament sometimes obliterates the joint-cavity, so as to convert the articulation into a syndesmosis. After middle life the articular surfaces lose their polish, become roughened, and the synovial membrane apparently disappears. In old age, the cartilages of most of the ribs become continuous with the sternum, and the joint cavities are consequently obliterated.

The **costoxiphoid ligaments** connect the anterior and posterior surfaces of the seventh costal cartilage, and sometimes those of the sixth, to the front and back of the xiphoid process. They vary in length and breadth in different subjects ; those on the back of the joint are less distinct than those in front.

Movements.—Slight gliding movements are permitted in the sternocostal joints.

THE INTERCHONDRAL JOINTS (fig. 518)

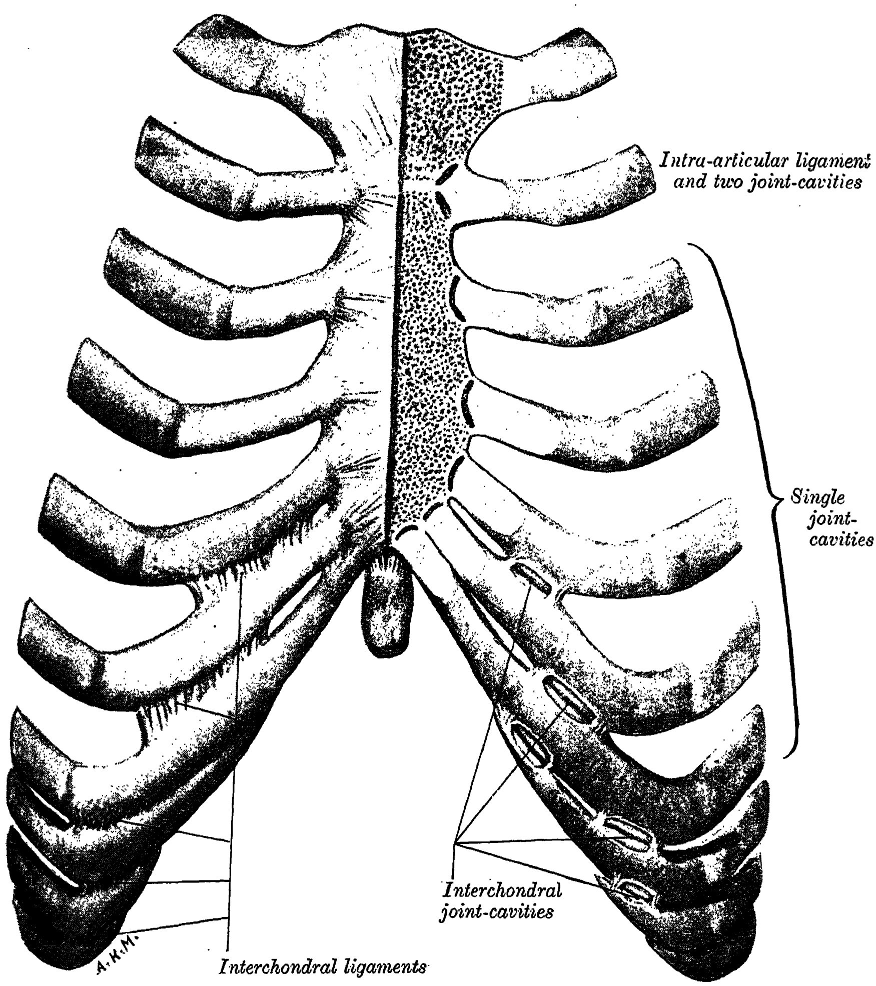
The contiguous borders of the sixth and seventh, the seventh and eighth, and the eighth and ninth, costal cartilages articulate with each other by small

smooth, oblong facets. Each articulation is enclosed in a thin *capsular ligament*, lined with synovial membrane and strengthened laterally and medially by *interchondral ligaments*, which pass from one cartilage to the other. Sometimes the fifth costal cartilages, more rarely the ninth, articulate by their lower borders with the adjoining cartilages by small, oval facets ; more frequently the connexion is by a few ligamentous fibres

The Costochondral Joints

The lateral end of each costal cartilage is received into a depression in the sternal end of the rib, and the two are enveloped by the periosteum.

Fig. 518.—The sternocostal and interchondral joints. Viewed from in front.



The Sternal Joints

The **manubriosternal joint.**—In the majority of cases the joint between the manubrium and the body of the sternum is cartilaginous in character, the bony surfaces being coated with hyaline cartilage and connected by a disc of fibro-

cartilage, which occasionally becomes ossified in advanced life. In rather more than thirty per cent. of subjects the central part of the disc undergoes absorption and the joint is converted into a synovial one. The two segments of the bone are also connected by the fibrous membrane which envelops the bone.

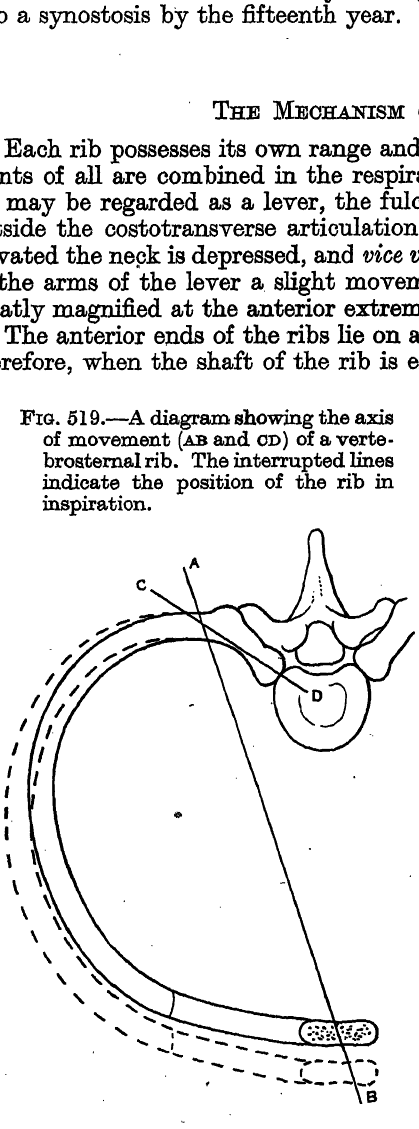
The **xiphisternal joint.**—The joint between the xiphoid process and the body of the sternum is also a secondary cartilaginous joint, but it is usually converted into a synostosis by the fifteenth year.

The Mechanism of the Thorax

Each rib possesses its own range and variety of movements, but the movements of all are combined in the respiratory excursions of the thorax. Each rib may be regarded as a lever, the fulcrum of which is situated immediately outside the costotransverse articulation, so that when the shaft of the rib is elevated the neck is depressed, and *vice versa* ; from the disproportion in length of the arms of the lever a slight movement at the vertebral end of the rib is greatly magnified at the anterior extremity.

The anterior ends of the ribs lie on a lower plane than the posterior ; and, therefore, when the shaft of the rib is elevated, the anterior extremity is also thrust forwards. Again, the middle of the shaft of the rib lies in a plane below that passing through the two extremities, so that when the shaft is elevated relatively to its ends it is at the same time carried outwards from the median plane ; further, each rib forms the segment of a curve which is greater than that of the rib immediately above. Therefore the elevation of a rib increases the transverse diameter of the thorax in the plane to which it is raised. The modifications of the rib movements at their vertebral ends have already been described (p. 447). Further modifications result from the attachments of their anterior extremities, and it is convenient therefore to consider separately the movements of the ribs of the three groups—vertebrosternal, vertebrochondral, and vertebral.

Fig. 519.—A diagram showing the axis of movement (AB and CD) of a vertebrosternal rib. The interrupted lines indicate the position of the rib in inspiration.

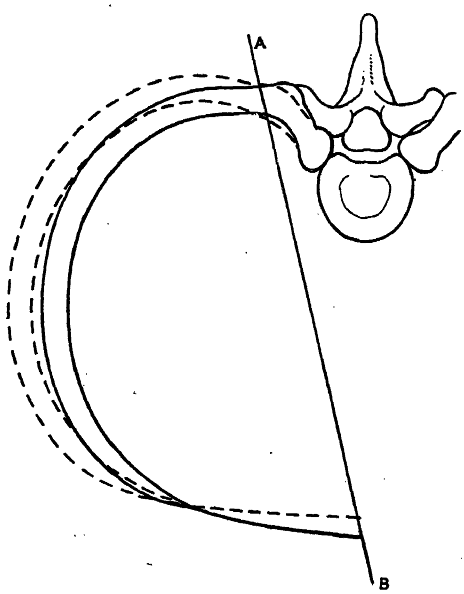


Vertebrosternal ribs (fig. 519).—The first rib differs from the others of this group in that its attachment to the sternum is a rigid one ; this is counter-balanced to some extent by the fact that its head possesses no intra-articular ligament, and is therefore more movable. The first pair of ribs with the manubrium sterni move as a single piece, the anterior portions being elevated by rotatory movements at the vertebral extremities. In normal quiet respiration the movement of this arc is practically *nil* ; when it does occur the anterior part is raised and carried forwards, increasing the anteroposterior diameter of this region of the chest. The movement of the second rib is also slight in normal respiration, as its anterior extremity is fixed to the manubrium, and therefore prevented from moving upwards. The sternocostal articulation, however, allows the middle of the shaft of the rib to be drawn up, and in this way the transverse thoracic diameter is increased. Elevation of the third, fourth, fifth, and sixth ribs raises and thrusts forwards their anterior extremities, the greater

part of the movement being effected by the rotation of the rib-neck backwards. The thrust of the anterior extremities carries forwards and upwards the body of the sternum, which moves on the joint between it and the manubrium, and thus the anteroposterior thoracic diameter is increased. This movement, however, is soon arrested, and the elevating force is then expended in raising the middle part of the shaft of the rib and everting its lower border; at the same time the costochondral angle is opened out. By these latter movements a considerable increase in the transverse diameter of the thorax is effected.

Vertebrochondral ribs (fig. 520).—The seventh rib is included with this group, as it conforms more closely to their type. While the movements of these ribs assist in enlarging the thorax for respiratory purposes, they are also concerned in increasing the upper abdominal space for viscera displaced by the action of the diaphragm. The costal cartilages articulate with one another, so that each pushes up that above it, the final thrust being directed to pushing forwards

FIG. 520.—A diagram showing the axes of movement (AB) of a vertebrochondral rib. The interrupted lines indicate the position of the rib in inspiration.



and upwards the lower end of the body of the sternum. The amount of elevation of the anterior extremities is limited on account of the very slight rotation of the rib-neck. Elevation of the shaft is accompanied by an outward and backward movement; the outward movement everts the anterior end of the rib and opens up the infracostal angle, while the backward movement pulls back the anterior extremity and counteracts the forward thrust due to its elevation; this latter is most noticeable in the lower ribs, which are the shortest. The total result is a considerable increase in the transverse and a diminution in the median anteroposterior diameter of the upper part of the abdomen; at the same time, however, the lateral anteroposterior diameters of the abdomen are increased.

Vertebral ribs.—Since these ribs have free anterior extremities and only costocentral articulations with no intra-articular ligaments, they are capable of slight movements in all directions. When the other ribs are elevated these are depressed and fixed to form points of action for the diaphragm.

Muscles producing the movements.—These are discussed with the mechanism of respiration (p. 558).

THE JOINTS OF THE UPPER LIMB

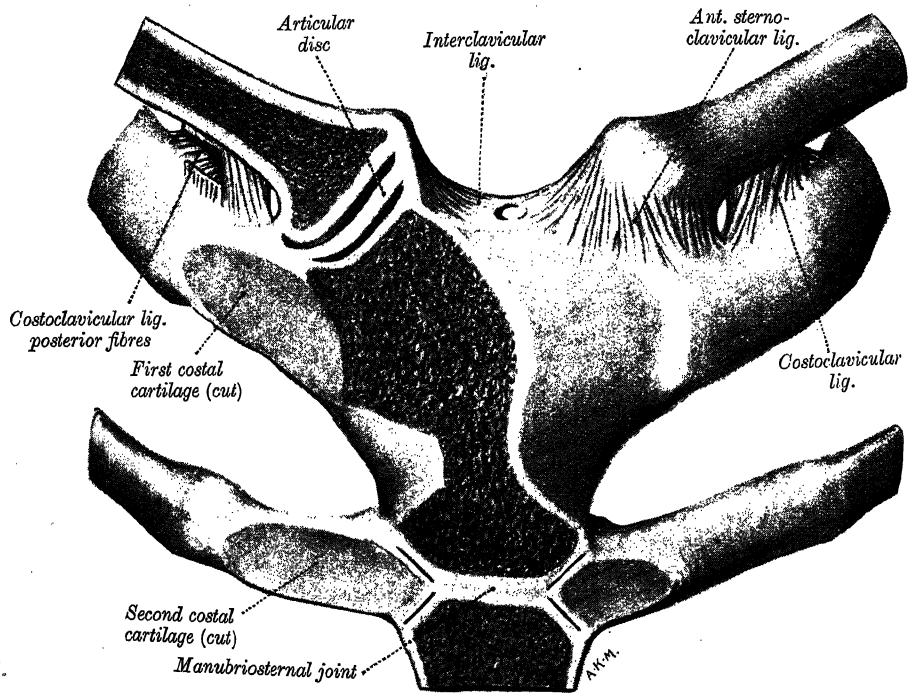
I. THE STERNOCLAVICULAR JOINT (fig. 521)

The sternoclavicular articulation is a double plane joint, the joint-cavity being subdivided by an articular disc. The parts entering into its formation are the sternal end of the clavicle, the clavicular notch of the manubrium sterni, and the cartilage of the first rib. The *articular surface* of the clavicle is much larger than that of the sternum, and is covered with a layer of fibrocartilage which is considerably thicker than that on the sternum. It is convex in its vertical diameter, and slightly concave anteroposteriorly. The clavicular notch of the sternum is reciprocally curved, but the two surfaces are not perfectly congruent and the incongruence is compensated for by the articular disc. In actual fact the joint functions rather as a ball-and-socket joint than as a saddle-joint. The ligaments of this joint are :

Capsular. Interclavicular.
Anterior sternoclavicular. Costoclavicular.
Posterior sternoclavicular.

The **capsular ligament** surrounds the articulation ; in front and behind, it is of considerable thickness, but above, and especially below, it is thin and partakes more of the character of areolar tissue than of true fibrous tissue.

FIG. 521.—The sternoclavicular joints ; viewed from in front.



The **anterior sternoclavicular ligament** is a broad band, covering the anterior surface of the joint ; it is attached above to the upper and front part of the sternal end of the clavicle, and, passing obliquely downwards and medially, is attached below to the front of the upper part of the manubrium sterni.

The **posterior sternoclavicular ligament** is a weaker band which covers the posterior aspect of the joint. It is attached to the posterior aspect of the sternal end of the clavicle and passes obliquely downwards and medially to be attached to the back of the upper part of the manubrium sterni.

The **interclavicular ligament** is continuous above with the deep cervical fascia ; it passes from the upper part of the sternal end of one clavicle to that

of the other, but gives some fibres to the upper margin of the manubrium sterni.

The **costoclavicular ligament** is short, flat, strong, and rhomboid in form. Attached below to the upper surface of the cartilage of the first rib, it is fixed above to the impression on the under surface of the medial end of the clavicle. The anterior fibres are directed upwards, backwards and laterally, the posterior fibres upwards, backwards and medially (fig. 521).

The **articular disc** is flat and nearly circular, and is interposed between the articulating surfaces of the sternum and clavicle. It is attached, above, to the upper and posterior border of the articular surface of the clavicle; below, to the cartilage of the first rib, near its junction with the sternum; and by the rest of its circumference to the capsular ligament. It is thicker at the circumference—especially at its upper and posterior part—than at the centre, and divides the joint into two cavities; each of its surfaces is clothed with synovial membrane.

The *arteries* supplying the joint are derived from the internal mammary and suprascapular (transverse scapular) arteries; the *nerves*, from the medial (anterior) supraclavicular nerves and the nerve to the subclavius muscle.

Applied Anatomy.—The strength of this joint depends upon its ligaments, and especially on the articular disc. It is owing to these, and to the fact that the force of the blow is usually transmitted along the long axis of the clavicle, that dislocation rarely occurs, and that the clavicle is broken rather than displaced. Dislocation may be either forwards, backwards or upwards. Should the clavicle be displaced backwards it may cause pressure on the trachea and great vessels of the neck. Owing to the shape of the articular surfaces, and the fact that the strength of the joint mainly depends upon the ligaments, the displacement when reduced is very liable to recur.

The joint is the fulcrum for the leverage exerted by the trapezius on the clavicle in elevation of the shoulder. If the joint is unstable, as the result of a dislocation, the effectiveness of the muscle is appreciably diminished.

II. THE ACROMIOCLAVICULAR JOINT

The acromioclavicular articulation (fig. 525) is a plane joint between the acromial end of the clavicle and the medial margin of the acromion of the scapula. The *articular surface* of the acromial end of the clavicle is covered with fibrocartilage, and forms a narrow, oval area, which is directed downwards and laterally so as to overlap the corresponding area on the medial border of the acromion. The long axis of the joint lies in an anteroposterior plane. Its ligaments are:

Capsular.	Coracoclavicular	Trapezoid part.
Acromioclavicular.		Conoid part.

The **capsular ligament** completely surrounds the articular margins, and is strengthened above by the acromioclavicular ligament.

The **acromioclavicular ligament** is a quadrilateral band, covering the superior part of the joint, and extending between the upper part of the acromial end of the clavicle and the adjoining part of the upper surface of the acromion; it is composed of parallel fibres, which interlace with the aponeuroses of the trapezius and deltoid muscles.

An **articular disc** is found sometimes in this joint; when present, it generally occupies the upper part of the articulation, and only partially separates the articular surfaces. More rarely, it divides the joint completely into two cavities.

The **coracoclavicular ligament** (fig. 522) connects the clavicle with the coracoid process of the scapula. It does not properly belong to the acromioclavicular joint, but is usually described with it since it forms a most efficient means of preventing the clavicle from losing contact with the acromion. It consists of two parts, viz. *trapezoid* and *conoid*, which are usually separated by a bursa.

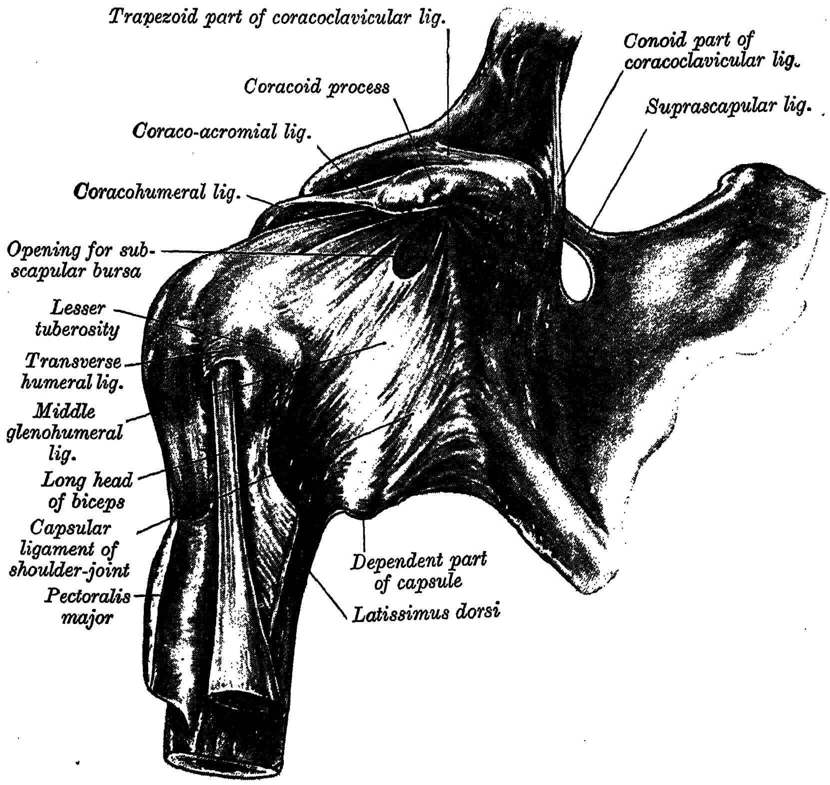
The *trapezoid part*, which forms the anterior and lateral fasciculus, is broad, thin, and quadrilateral. It is attached, below, to the upper surface of the

coracoid process; above, to the trapezoid line on the under surface of the clavicle. Its anterior border is free; its posterior is joined with the conoid part, the two forming, by their junction, an angle projecting backwards.

The *conoid part*, which forms the posterior and medial fasciculus, is a dense band of fibres, conical in form, with its base directed upwards. Its apex is attached to a rough impression at the junction of the root with the horizontal portion of the coracoid process, medial to the trapezoid part; its base is fixed to the conoid tubercle on the under surface of the clavicle, and to a line proceeding medially from it for 1·25 cm.

The *arteries* supplying the joint are derived from the suprascapular (transverse scapular) and acromiothoracic arteries; the *nerve* is a branch of the suprascapular nerve.

FIG. 522.—The right shoulder-joint. Anterior aspect.



Movements of the shoulder girdle.—The movements which occur at the sternoclavicular and acromioclavicular joints are always associated with movements of the scapula, and movements of the scapula are usually, though not invariably, associated with movements of the humerus at the shoulder joint. The movements of the scapula and clavicle *per se* are of academic interest only, but they are of great practical importance when they are considered from the point of view of their relation to the movements of the humerus. The student, therefore, is advised to keep this in mind when reading the following paragraphs, and, on their conclusion, he should turn to the paragraphs dealing with the movements at the shoulder-joint itself (p. 459).

The acromioclavicular joint allows the acromion to glide forwards and backwards, and to rotate upwards and downwards on the clavicle, but the range of these scapular movements is greatly increased by associated movements which occur at the sternoclavicular joint at the same time. The analysis of all these movements can be effected by a study of the movements of the scapula.

The following movements of the scapula are permitted: (1) elevation and

depression; (2) forward and backward movement round the chest wall; (3) rotation forwards (or upwards) and rotation backwards (or downwards).

(1) *Elevation* or *depression of the scapula*, e.g. shrugging of the shoulders, does not necessarily imply any corresponding movement at the shoulder-joint. (*a*) During elevation only a slight degree of angular movement occurs at the acromioclavicular joint, but the sternal end of the clavicle moves downwards over the surface of the articular disc. This movement at the sternoclavicular joint is checked by tension of the antagonist muscles, the costoclavicular ligament and the lower part of the capsule. It is brought about by the *trapezius* (*upper fibres*) and the *levator scapulæ*, and, as these muscles tend to rotate the scapula in opposite directions, a pure upward movement is effected.

(*b*) In the reverse movement a little angular movement occurs at the acromioclavicular joint, but at the sternoclavicular joint the clavicle rides upwards on the disc, and this movement is checked by tension of the antagonist muscles, and by the interclavicular and sternoclavicular ligaments and the articular disc. In extreme depression of the point of the shoulder, such as may occur when a heavy weight is carried on it, the sternal end of the clavicle may be supported by the first rib. As a rule this movement is carried out with the help of the force of gravity, but it can be performed actively by the *serratus anterior* (*lower fibres*) and the *pectoralis minor*.

(2) (*a*) *Forward movement of the scapula* round the chest wall occurs in all forward pushing, thrusting and punching movements, and it is usually accompanied by some degree of forward rotation. The acromion moves forwards over the clavicular facet to the limit of its range of movement, and at the same time the point of the shoulder is advanced further by a forward movement of the lateral end of the clavicle. This forward movement is associated with a backward movement of the sternal end of the bone, which moves backwards over the sternal facet, carrying the articular disc with it. Tension of the antagonist muscles, of the posterior sternoclavicular ligament and of the posterior fibres of the costoclavicular ligament checks this backward movement. The *serratus anterior* and the *pectoralis minor* are the prime movers, and this combination ensures the continuous apposition of the medial border of the scapula with the chest wall. In addition, the "strap" effect of the upper fibres of the latissimus dorsi keeps the inferior angle in close contact with the ribs, both in this movement and in forward rotation.

(*b*) In *backward movement of the scapula*, such as occurs when the shoulders are braced back, the reverse movements take place and they are checked at the sternoclavicular joint by tension of the anterior sternoclavicular ligament and of the anterior fibres of the costoclavicular ligament. When it is carried out actively or against resistance, the *trapezius* and the *rhomboid muscles* are the prime movers.

It may be noted here that when force is applied at the extremity of the outstretched arm, e.g. by a fall on the hand, the pressure transmitted to the glenoid cavity tends to drive the sloping acromial facet below the acromial end of the clavicle, but at the same time it causes tension of the trapezoid ligament, which serves to resist the displacement.

(3) (*a*) *Forward rotation of the scapula* serves to increase the range of movement of the humerus, by turning the bone so that the glenoid cavity faces almost directly upwards—the position which it assumes when the arm is raised above the head. This movement is always associated with some degree of elevation of the humerus and is accompanied by some forward movement of the scapula round the chest wall. The acromial facet rotates upwards on the clavicle and at the same time the point of the shoulder is raised. The rotation results in tension of the conoid ligament at a relatively early stage and thereafter the clavicular attachment of the ligament appears to serve as the centre around which the subsequent movement takes place. Thus throughout the greater part of the movement the conoid ligament is kept taut and it helps to bring about the upward rotation of the clavicle which usually occurs in the last stage. This rotatory movement of the clavicle is very small in extent and is checked by the tension of the articular disc, the sternoclavicular capsule and the costoclavicular ligament.

In this important movement the *trapezius* and the *serratus anterior* are the prime movers.

(*b*) The opposite rotation is usually effected under the influence of gravity, and the gradual relaxation of the trapezius and serratus anterior is sufficient to bring it about. When it is performed actively, the *levator scapulæ*, the *rhomboids*, and, in the initial stages at least, the *pectoralis minor* are the prime movers so far as the scapula is concerned.

In all the movements of the scapula the *subclavius muscle* serves to steady the clavicle by drawing it medially and downwards.

Attention should be drawn to the fact that in the movements of the scapula, muscles which are antagonists for one type of movement may nevertheless combine together and act as prime movers for another. Thus the serratus anterior and the trapezius are opposed in forward and backward movements round the chest wall, but combine together as prime movers for forward rotation.

THE LIGAMENTS OF THE SCAPULA

The ligaments of the scapula (fig. 522) are the coraco-acromial, the suprascapular (superior transverse), and the spinoglenoid (inferior transverse).

The **coraco-acromial ligament** is a strong triangular band, extending between the coracoid process and the acromion. Its apex is attached to the edge of the acromion just in front of the articular surface for the clavicle ; and its base to the whole length of the lateral border of the coracoid process. This ligament, together with the coracoid process and the acromion, forms an arch for the protection of the head of the humerus. It sometimes consists of two strong marginal bands and a thinner intervening portion.

When the pectoralis minor is inserted, as it is occasionally, into the capsule of the shoulder-joint instead of into the coracoid process, the tendon of the muscle passes between the two bands of the coraco-acromial ligament.

The **suprascapular (superior transverse) ligament** converts the suprascapular notch into a foramen, and is sometimes ossified. It is a thin and flat fasciculus, narrower at the middle than at the extremities, which are attached to the base of the coracoid process and the medial end of the suprascapular notch respectively. The suprascapular nerve runs through the foramen ; the suprascapular (transverse scapular) vessels cross over the ligament.

The **spinoglenoid (inferior transverse) ligament** is a weak, membranous band, stretching from the lateral border of the spine of the scapula to the margin of the glenoid cavity. It forms an arch under which the suprascapular nerve and vessels enter the infraspinous fossa. It is frequently absent.

III. THE SHOULDER-JOINT

The shoulder-joint (figs. 522 to 527) is a ball-and-socket joint. The bones entering into its formation are the hemispherical head of the humerus and the shallow glenoid cavity of the scapula, a construction which permits of very considerable movement but seriously affects the stability of the joint. Structurally the shoulder-joint is weak, since, for such strength as it possesses, it is dependent on the support given by the muscles which surround it and not on its bony conformation or the presence of any strong ligaments. It is, however, protected above by an arch, formed by the coracoid process, the acromion and the coraco-acromial ligament.

The *articular surfaces* are reciprocally curved, but as the head of the humerus is much larger than the glenoid cavity only a portion of it can be in contact with the cavity in any given position of the joint. The glenoid cavity is deepened somewhat by a fibrocartilaginous rim attached to its margins and termed the *glenoidal labrum*. Both articular surfaces are covered with a layer of hyaline cartilage ; that on the head of the humerus is thickest at its centre and thinner peripherally, while the reverse is the case in the glenoid cavity.

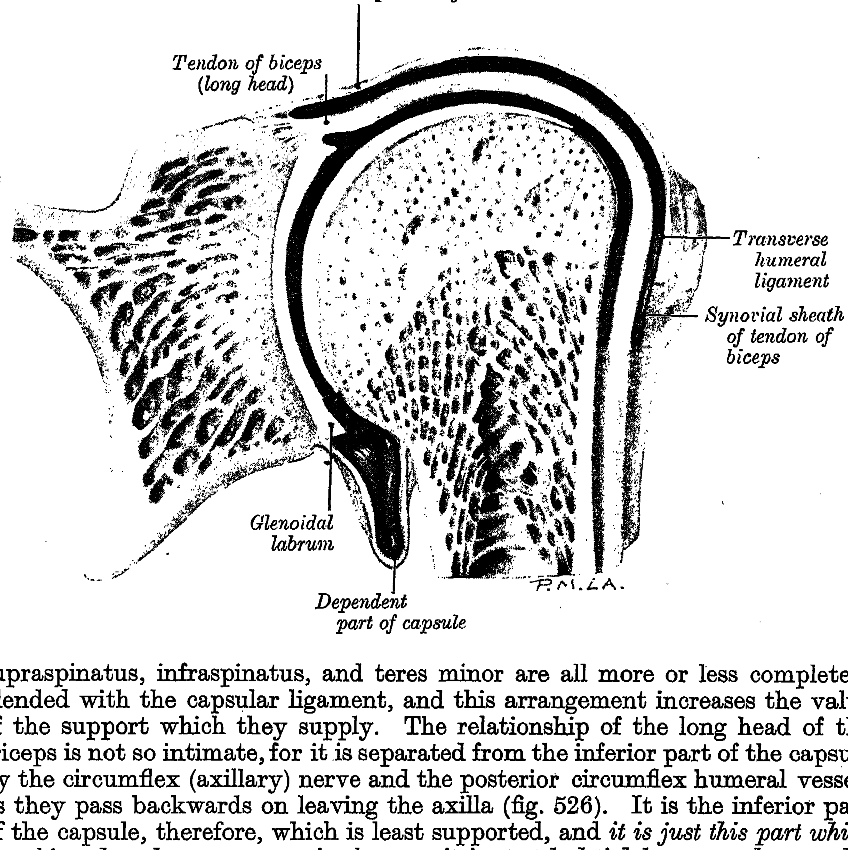
The ligaments of the articulation are :

Capsular.	The glenoidal labrum.
Coracohumeral.	Transverse humeral.

The **capsular ligament** (figs. 522, 523) envelops the joint, and is attached, medially, to the circumference of the glenoid cavity beyond the glenoidal

labrum ; above, it encroaches on to the root of the coracoid process so as to include the origin of the long head of the biceps within the joint. Laterally it is attached to the anatomical neck of the humerus, except on the medial side where it descends for rather more than 1 cm. on to the shaft of the bone. It is so remarkably loose and lax that the bones may be separated from each other for a distance of 2 or 3 cm., an evident provision for the great freedom of movement which is permitted at this articulation. *It should be noted, however, that this separation can be effected only after the superior part of the ligament has been relaxed by the movement of abduction.* The capsular ligament is strengthened, above, by the supraspinatus ; below, by the long head of the triceps ; behind, by the tendons of the infraspinatus and teres minor ; and in front, by the tendon of the subscapularis. The tendons of the subscapularis,

FIG. 523.—A section through the shoulder joint. The synovial membrane is shown in blue.



supraspinatus, infraspinatus, and teres minor are all more or less completely blended with the capsular ligament, and this arrangement increases the value of the support which they supply. The relationship of the long head of the triceps is not so intimate, for it is separated from the inferior part of the capsule by the circumflex (axillary) nerve and the posterior circumflex humeral vessels as they pass backwards on leaving the axilla (fig. 526). It is the inferior part of the capsule, therefore, which is least supported, and *it is just this part which is subjected to the greatest strain, because it is stretched tightly across the rounded head of the humerus when the arm is abducted.*

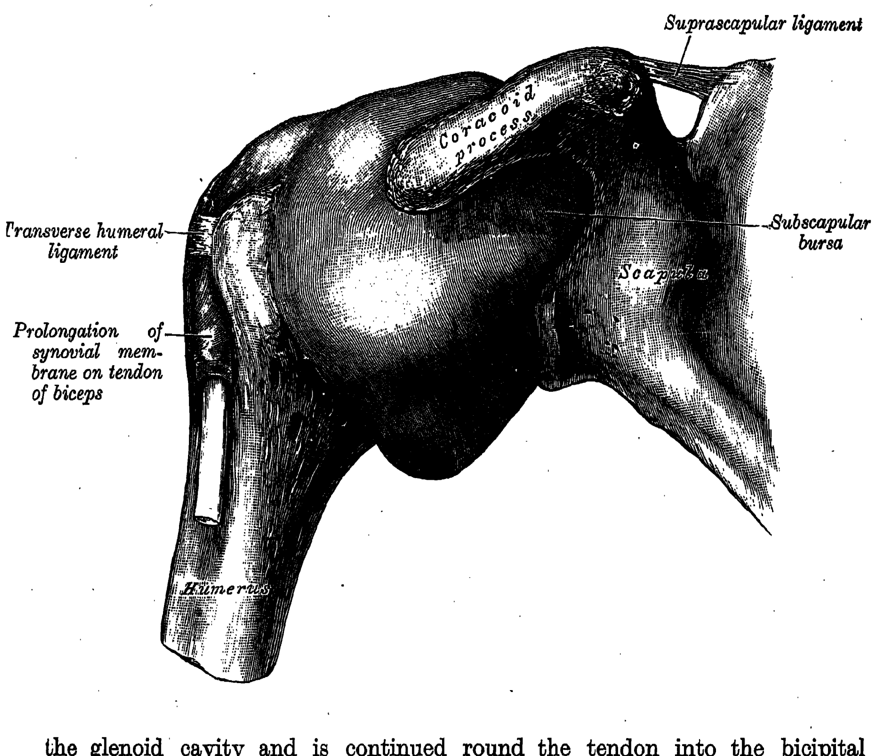
There are usually two, occasionally three, openings in the capsule. One, situated anteriorly, below the coracoid process, establishes a communication between the joint and a bursa behind the tendon of the subscapularis ; another, placed between the tuberosities of the humerus, gives passage to the long tendon of the biceps and its synovial sheath ; the third, which is not constant, is at the posterior part, between the joint and a bursal sac under the tendon of the infraspinatus.

Three supplemental bands (fig. 525), which are named the *glenohumeral ligaments,* strengthen the capsule. These are best seen by opening the posterior part of the capsule of the joint and removing the head of the humerus. At their scapular ends they are all attached to the upper part of the medial margin of the glenoid cavity and are intimately connected with the glenoidal labrum. The superior band passes along the medial edge

of the tendon of biceps and is attached to a small depression above the lesser tuberosity of the humerus; the middle band reaches to the lower part of the lesser tuberosity; the inferior band extends to the lower part of the anatomical neck of the humerus. In addition to these, the capsule is strengthened in front by two bands, one derived from the tendon of the pectoralis major, the other from the tendon of the teres major.

The *synovial membrane* is reflected from the margin of the glenoid cavity over the glenoidal labrum; it is then continued over the inner surface of the capsular ligament, and covers the lower part and sides of the anatomical neck of the humerus as far as the articular cartilage on the head of the bone. The tendon of the long head of the biceps passes through the joint and is enclosed in a tubular sheath of synovial membrane, which is reflected upon it from the summit of

FIG. 524.—The synovial cavity of the right shoulder-joint (distended). Anterior aspect. (From a specimen prepared by J. C. B. Grant.)



the glenoid cavity and is continued round the tendon into the bicipital groove (intertubercular sulcus) as far as the surgical neck of the humerus (figs. 523, 524).

The **coracohumeral ligament** (fig. 522) is a broad band which strengthens the upper part of the capsule. It is attached to the lateral border of the root of the coracoid process, and passes obliquely downwards and laterally to the front of the greater tuberosity of the humerus, blending with the tendon of the supraspinatus. The posterior and lower border of the ligament is united to the capsular ligament; its anterior and upper border is free, and overlaps the capsular ligament.

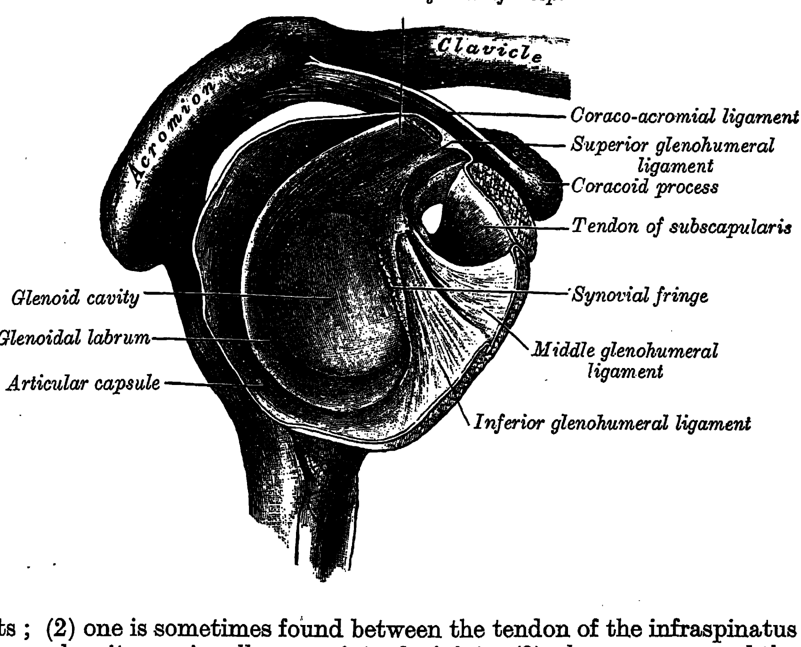
The **transverse humeral ligament** (fig. 524) is a broad band passing from the lesser to the greater tuberosity of the humerus; it converts the bicipital groove (intertubercular sulcus) into a canal, and its attachment is always limited to that portion of the bone which lies above the epiphyseal line. Although it is continuous above with the capsular ligament, the transverse humeral ligament functions simply as a retinaculum for the tendon of the long head of the biceps muscle and plays no other part in the movements of the joint.

The **glenoidal labrum** (figs. 525, 526) is a fibrocartilaginous rim attached round the margin of the glenoid cavity. It is triangular on section, the base

being fixed to the circumference of the cavity, while the free edge is thin and sharp. It is continuous above with the tendon of the long head of the biceps, which gives off two fasciculi to blend with the fibrous tissue of the labrum. It deepens the articular cavity, and protects the edges of the bone. Its attachment to the margin of the glenoid cavity is sometimes deficient in parts; the deficiency occurs most commonly at the notch on the upper part of the antero-medial margin, and a small fringe of the synovial membrane occasionally protrudes through the gap.

Bursæ.—The bursæ in the neighbourhood of the shoulder-joint are the following: (1) one is constantly found between the tendon of the subscapularis and the joint-capsule (fig. 526): it communicates with the joint cavity through an opening which is situated between the superior and the middle glenohumeral

Fig. 525.—Interior of shoulder-joint. Viewed from the lateral side.



ligaments; (2) one is sometimes found between the tendon of the infraspinatus and the capsule; it occasionally opens into the joint; (3) a large one, named the *subacromial bursa* (fig. 526), exists between the deltoid and the capsule; it does not communicate with the joint, but is prolonged under the acromion and coraco-acromial ligament, and intervenes between these structures and the supraspinatus, which covers the upper part of the capsule; (4) a large one is situated on the summit of the acromion; (5) one is frequently found between the coracoid process and the capsule; (6) one sometimes exists behind the coracobrachialis; (7) one lies between the teres major and the long head of the triceps; (8) one is placed in front of, and another behind, the tendon of the latissimus dorsi.

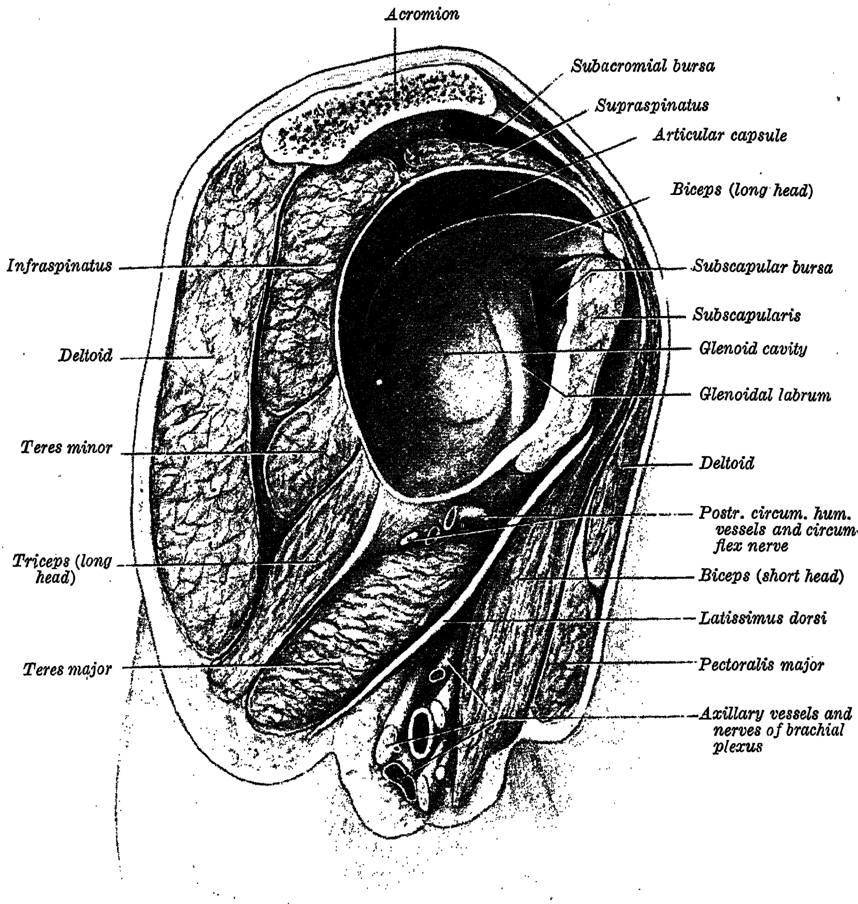
The *muscles* in relation with the joint are, above, the supraspinatus; below, the long head of the triceps; in front, the subscapularis; behind, the infraspinatus and teres minor; within, the tendon of the long head of the biceps. The deltoid covers the joint in front, behind and laterally (fig. 526).

The *arteries* supplying the joint are derived from the anterior and posterior circumflex humeral, and suprascapular (transverse scapular) arteries; the *nerves*, from the circumflex (axillary) and suprascapular nerves.

Movements.—The shoulder is a ball-and-socket joint, and therefore is capable of flexion, extension, abduction, adduction, circumduction and rotation. The laxity of its capsular ligament and the large size of the head of the humerus compared with that of the shallow glenoid cavity give to the shoulder a wider range of movement than is possible at any other joint.

When the movements at the shoulder-joint are being analysed, the humerus should be considered in its relationship to the scapula and not in its relationship to the sagittal and coronal planes of the trunk. When the arm is by the side in the resting position, the glenoid cavity faces almost equally forwards and laterally, and the position of the humerus corresponds to that of the scapula, although relative to the trunk it appears to be rotated medially (p. 346). As a result *flexion* carries the arm forwards and medially across the front of the chest, and the movement takes place around an axis which passes through the head of the humerus at right angles to the plane of the glenoid cavity at

FIG. 526.—Structures in relation with the shoulder-joint.

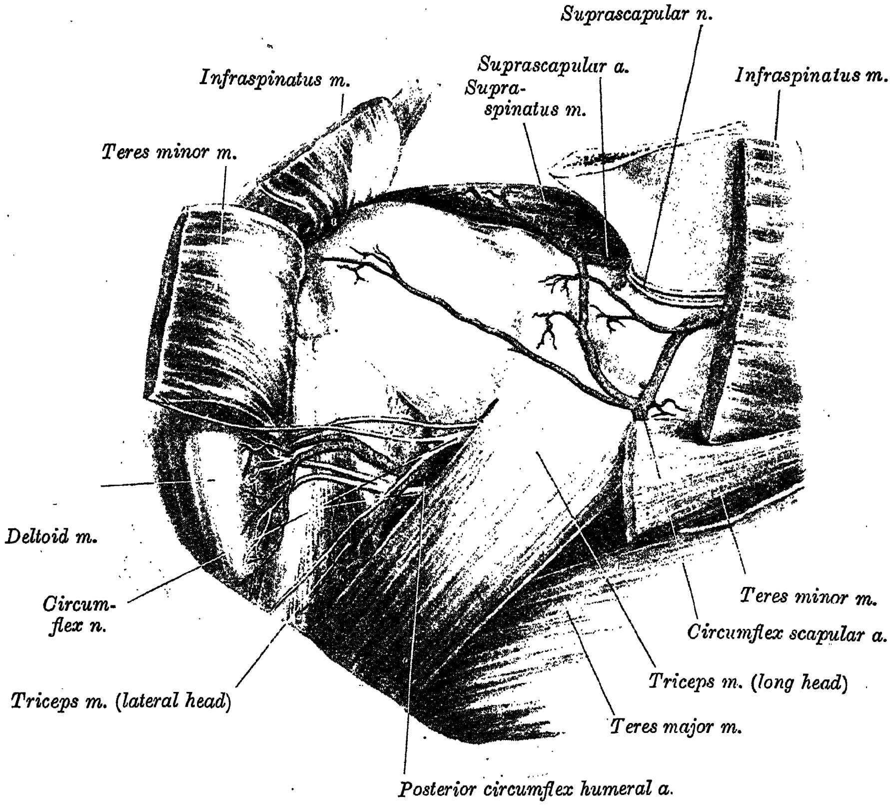


(approximately) its centre. *Abduction* and *adduction* occur in a plane at right angles to the plane of flexion and extension, and the axis passes through the head of the humerus parallel to the plane of the glenoid cavity.* Abduction therefore carries the arm forwards and laterally away from the trunk, and *the movement occurs in the plane of the body of the scapula.* At the shoulder-joint itself the movements of flexion and abduction are limited to approximately 90° ; when the arm is raised vertically above the head the additional (approximately) 90° are obtained by forward rotation of the scapula (p. 455). In flexion,

* Many writers prefer to consider flexion and extension as occurring in a paramedian plane, and abduction and adduction as occurring in a coronal plane, i.e. they prefer to regard the movements as being relative to the trunk and not to the scapula. *The reader is warned that, if he prefers to accept these definitions, he must regard the deltoid and supraspinatus muscles as producing a combination of flexion and abduction, for working as a combination they*

however, the humerus moves in a plane at right angles to the plane of the body of the scapula, and no amount of rotation of the scapula can increase the degree of elevation (90°) obtained in full flexion. If the fully flexed humerus is gradually abducted, the degree of elevation increases *pro rata*, until, when the humerus comes to lie in the plane of the body of the scapula, i.e. when the position of pure abduction is reached, the full 180° of elevation is obtained. In *rotation*, which may be medial or lateral, the humerus revolves for about one-quarter of a circle about its own long axis. The range of rotatory movement is greatest when the arm is by the side, and least when it is raised to the vertical. In *circumduction*, which results from a succession of the foregoing

FIG. 527.—The posterior aspect of the left shoulder-joint.



An oblique saw-cut has been made through the spine of the scapula and the acromion has been removed. Portions of the infraspinatus and teres minor muscles have been excised and their tendons have been turned forwards.

movements, the lower end of the humerus describes the base of a cone, the apex of which is at the head of the bone, but this movement at the shoulder-joint can be increased very substantially by the movements of the scapula, and the combination is well exemplified in the arm movements of a fast bowler in cricket.

do not raise the arm in a coronal plane. When the humerus is raised to the vertical from a position of flexion (in this sense), it undergoes a process of medial rotation, for which the deltoid (anterior fibres), the subscapularis and, probably, the supraspinatus are responsible. In the same way when the humerus is raised to the vertical from the position of abduction (in this sense), it undergoes a process of lateral rotation. In both cases the effect of the rotation is to bring the humerus into the same position relative to the scapula as it occupies when the arm is raised to the vertical in the plane of the body of the scapula, i.e. the movement described in the text as true abduction. When the arm is elevated in a natural way from the side, the humerus moves throughout in the plane of the body of the scapula and undergoes no appreciable rotation. (C. P. Martin, *British Journal of Surgery*, vol. xx. 1932, and T. B. Johnston, *British Journal of Surgery*, vol. xxv. 1937.)

When the arm is raised above the head, the movement of the humerus and the movements of the scapula and clavicle (p. 454) are combined and occur simultaneously, so that while the humerus is being raised relative to the scapula, the scapula itself is being rotated in a forward direction.*

The peculiar relation of the tendon of the long head of the biceps to the shoulder-joint appears to subserve various purposes. By its connexion with both the shoulder and elbow the muscle harmonises the action of the two joints, and acts as an elastic ligament during all the movements which occur at these articulations. It strengthens the upper part of the shoulder-joint, and prevents the head of the humerus from being pressed up against the acromion when the deltoid contracts; it thus fixes the head of the humerus as the centre of motion in the glenoid cavity. By its passage along the bicipital groove (intertubercular sulcus) it assists in steadying the head of the humerus in the various movements of the arm.

Owing to the shallowness of the glenoid cavity and the laxity of the capsule, a wide range of *accessory movements* (p. 431) is possible at the shoulder-joint. The head of the humerus can be moved backwards, forwards, upwards and downwards in relation to the glenoid cavity and, when the arm is abducted—the position in which the accessory movements are most free—it can be separated from it by traction.

Muscles producing the movements.—The muscles moving the shoulder may be divided into: (*a*) those acting on the shoulder-girdle and (*b*) those acting on the shoulder-joint.

(*a*) **Muscles acting on the shoulder-girdle.**—These muscles have already been considered in connexion with the movements of the shoulder-girdle (p. 455).

(*b*) **Muscles acting on the shoulder-joint.**

In **flexion**, the *pectoralis major* (*clavicular head*) (p. 586), the *deltoid* (*anterior fibres*) and the *coracobrachialis* are the principal muscles concerned, but they are assisted by the biceps and the subscapularis, and the *sternocostal head of the pectoralis major* plays an important part when the arm is drawn forwards to the plane of the trunk from the fully extended position.

In **extension**, the *deltoid* (*posterior fibres*) and the *teres major* are the principal muscles concerned when the movement starts with the arm by the side, but, when the fully flexed arm is extended against resistance, the *latissimus dorsi*, the infraspinatus, the teres minor, the long head of triceps, and the *sternocostal head of the pectoralis major* are powerful adjuvants until the arm reaches the plane of the body.

In **abduction**, the movement is probably initiated by the *supraspinatus* and is then carried on by the *deltoid*, which is capable of maintaining the position of abduction against very great resistance.

In **adduction** the *pectoralis major* and the *latissimus dorsi* are the principal muscles concerned, but the *teres major*, the *coracobrachialis* and, to a lesser extent, the subscapularis, the infraspinatus, the teres minor, the biceps and the triceps (long head) all participate.

Medial rotation is brought about by the *pectoralis major*, the *deltoid* (*anterior fibres*), the *latissimus dorsi*, the *teres major* and the *subscapularis*.

Lateral rotation is brought about by the *infraspinatus*, the *teres minor* and the *deltoid* (*posterior fibres*).

Applied Anatomy.—Owing to the construction of the shoulder-joint and the wide range of movement which it enjoys, as well as in consequence of its exposed situation, it is more frequently dislocated than any other joint. Dislocation occurs when the arm is abducted. In that position the head of the humerus presses against the lower and front part of the capsule, which is the thinnest and least supported part of the ligament. The rent in the capsule almost invariably takes place in this situation, and through it the head of the bone escapes, so that the dislocation in most instances is primarily subglenoid. If, after the dislocation has been reduced, abduction of the arm is prevented, the dislocation cannot recur.

* C. W. Cathcart, *Journal of Anatomy and Physiology*, vol. xviii., and R. D. Lockhart, *Journal of Anatomy*, vol. lxiv.

When the shoulder-joint is ankylosed, the loss of movement in the joint is partly compensated for by increased mobility of the scapula. In treating conditions of the shoulder-joint likely to lead to ankylosis, the humerus should be kept in the position it assumes when the palm of the hand is placed on the back of the neck, i.e. abducted, and slightly rotated laterally so as to make full use of this compensating mobility of the scapula.

IV. THE ELBOW-JOINT

The elbow-joint includes two articulations: (1) *humero-ulnar*, between the trochlea of the humerus and the trochlear notch (semilunar notch) of the ulna, and (2) *humeroradial*, between the capitulum of the humerus and the facet on the head of the radius. The joint-cavity and the articular capsule of the elbow-joint are continuous with the corresponding parts of the superior radio-ulnar joint, and these articulations are sometimes grouped together as the *cubital articulation*.

The *articular surfaces* concerned are the trochlea and capitulum of the humerus, on the one hand, and the trochlear notch of the ulna and the head of the radius, on the other. The trochlea is not a simple pulley, for its medial flange is much more extensive than its lateral flange and projects downwards to a lower level, so that the transverse axis of the joint, which lies below the level of the epicondyles, passes from the lateral side downwards and medially. In addition, the trochlea is widest where it covers the posterior aspect of the bone and in this position its lateral edge forms a salient ridge. The trochlear notch is by no means perfectly congruent with the trochlea. In full extension the medial part of its upper (olecranon) half is not in contact with the trochlea, and a corresponding strip on the lateral side loses contact on flexion. The olecranon and coronoid parts of the trochlear notch are usually separated by a narrow, roughened strip of bone, devoid of articular cartilage and covered with a little fibro-fatty tissue lined with synovial membrane. The capitulum and the head of the radius are reciprocally curved, but the best contact is obtained when the semiflexed radius is in the midprone position. The rim of the head fits into the groove between the capitulum and the trochlea.

The humero-ulnar and humeroradial articulations together form a ginglymus or hinge-joint, the ligaments of which are:

Capsular.	Anterior.	Medial.
	Posterior.	Lateral.

The **capsular ligament** (figs. 530 to 532).—The anterior part of the capsular ligament is a broad and thin fibrous layer, and constitutes the **anterior ligament** of the elbow-joint. It is attached, above, to the front of the medial epicondyle and to the front of the humerus immediately above the coronoid and radial fossæ; below, to the anterior surface of the coronoid process of the ulna and to the annular ligament (p. 468), being continuous at the sides with the medial and lateral ligaments. Its superficial fibres pass obliquely from the medial epicondyle of the humerus to the annular ligament. The middle fibres, vertical in direction, pass from the upper part of the coronoid depression and become partly blended with the preceding, but are inserted mainly into the anterior surface of the coronoid process. The deep or transverse set intersects these at right angles. Anteriorly the ligament is in relation with the brachialis and receives numerous fibres from its deep surface.

The posterior part of the capsular ligament is thin and membranous, and consists of transverse and oblique fibres, which constitute the **posterior ligament** of the elbow-joint. Above, it is attached to the humerus immediately behind the capitulum and close to the medial margin of the trochlea, to the margins of the olecranon fossa, and to the back of the lateral epicondyle some little distance from the trochlea. Below, it is fixed to the upper and lateral margins of the olecranon, to the posterior part of the annular ligament, and to the ulna behind the radial notch. It is in relation, behind, with the tendon of the triceps and the anconeus muscle.

The *synovial membrane* (figs. 528 to 530) is very extensive. It extends from the margin of the articular surface of the humerus, and lines the coronoid, radial and olecranon fossæ on that bone and covers the flattened medial surface of the trochlea (fig. 407); it is reflected over the deep surface of the capsular ligament and lines the deep surface of the annular ligament. Projecting into the joint-cavity between the radius and ulna from behind there is a crescentic fold of the synovial membrane, suggesting the division of the joint into two:

Fig. 528.—The synovial cavity of the left elbow-joint (distended). Anterior aspect. (From a specimen prepared by J. C. B. Grant.)

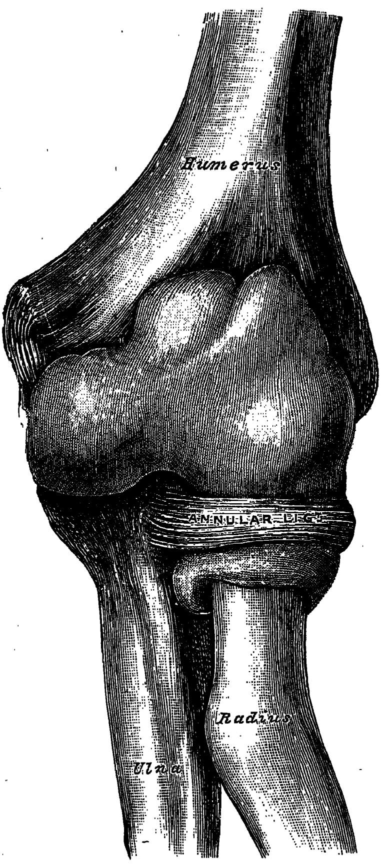
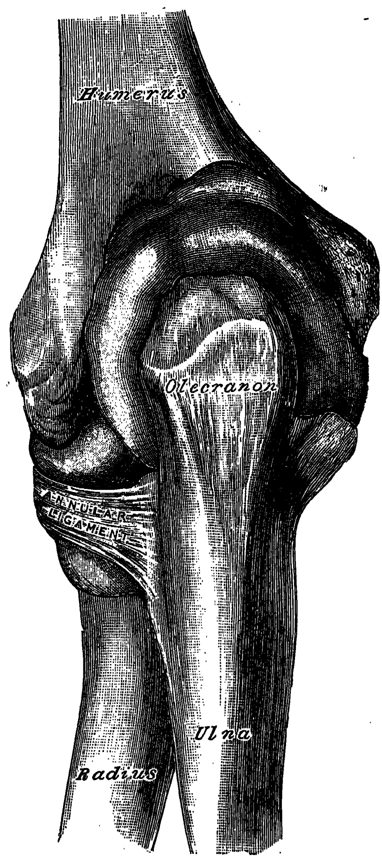


Fig. 529.—The synovial cavity of the left elbow-joint (distended). Posterior aspect of the specimen represented in fig. 528.



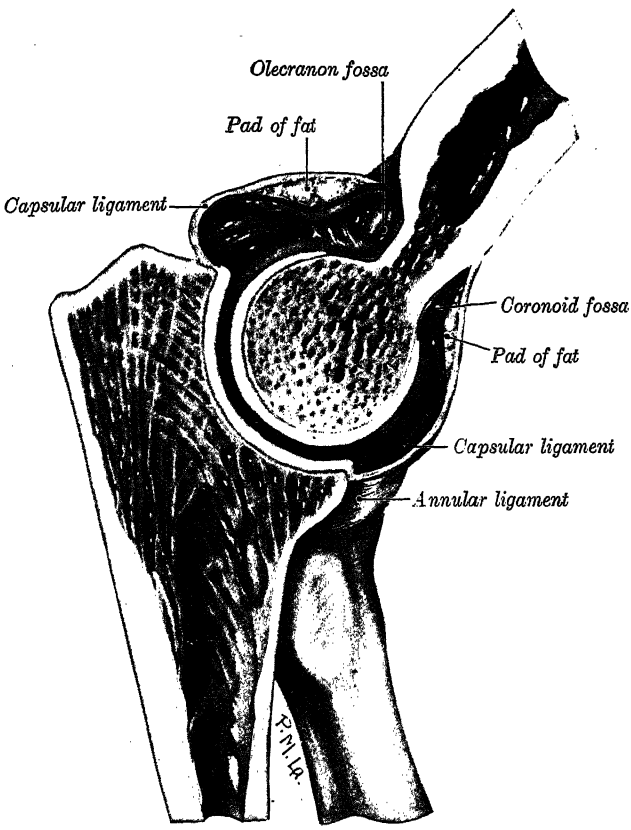
one the humeroradial, the other the humero-ulnar. This fold is irregularly triangular in outline and contains a variable quantity of extrasynovial fat.

Between the capsular ligament and the synovial membrane there are three other pads of fat. The largest, over the olecranon fossa, is pressed into the fossa by the triceps during flexion of the joint; the second, over the coronoid fossa, and the third, over the radial fossa, are pressed by the brachialis into their respective fossæ during extension. In addition, smaller tags of fat covered with synovial membrane project into the joint-cavity opposite to the constrictions on each side of the trochlear notch (p. 355), and cover the small non-articular areas of the bone in these situations.

The **medial ligament of the elbow-joint (ulnar collateral ligament)** (fig. 531) is a thick triangular band consisting of two portions, an anterior and a posterior, united by a thinner intermediate portion. The *anterior portion* is attached above, by its apex, to the front part of the medial epicondyle of the humerus; and below, by its broad base, to a tubercle on the upper part of the medial margin of the coronoid process. The *posterior portion*, also of triangular form,

is attached, above, to the lower and back part of the medial epicondyle; below, to the medial margin of the olecranon. Between these two bands a few intermediate fibres descend from the medial epicondyle to an *oblique head*—often feebly developed—which stretches between the olecranon and coronoid processes. This band converts the depression on the medial margin of the trochlear (semilunar) notch into a foramen, through which the intracapsular pad of fat is continuous with the extracapsular fat on the medial side of the joint. The medial ligament is in relation with the triceps and flexor carpi

FIG. 530.—A sagittal section through the left elbow-joint. The synovial membrane is shown in *blue*.



ulnaris *and the ulnar nerve*. Along its anterior portion the origin of the flexor digitorum sublimis extends from the medial epicondyle of the humerus downwards and laterally to the medial border of the coronoid process of the ulna.

The lateral ligament of the elbow-joint (radial collateral ligament) (fig. 532) is attached, above, to the lower part of the lateral epicondyle of the humerus, and below to the annular ligament, some of its most posterior fibres passing over that ligament to be inserted into the lateral margin of the ulna. It is intimately blended with the origins of the supinator and the extensor carpi radialis brevis.

The *muscles* in relation with the joint are, in front, the brachialis; behind, the triceps and anconeus; laterally, the supinator, and the common tendon of origin of the extensor muscles; medially, the common tendon of origin of the flexor muscles, and the flexor carpi ulnaris.

The *arteries* of supply are derived from the anastomotic network around the joint (p. 748).

The *nerves* of the joint consist of a twig from the ulnar nerve; one from the branch of the musculocutaneous nerve to the brachialis; one from the radial nerve; and two from the median nerve.

Fig. 531.—The left elbow-joint. Viewed from the medial side.

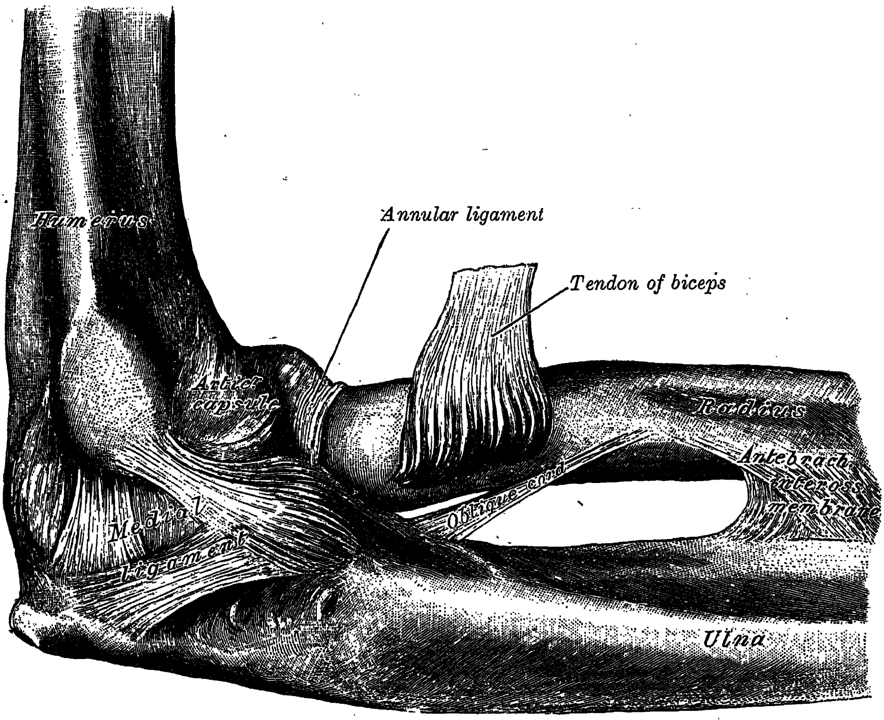
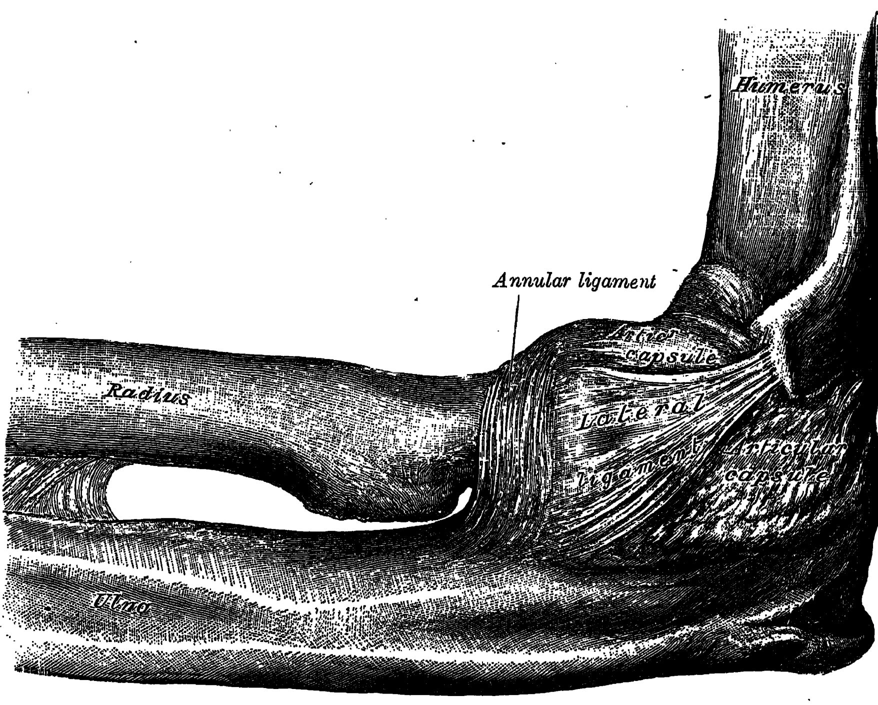


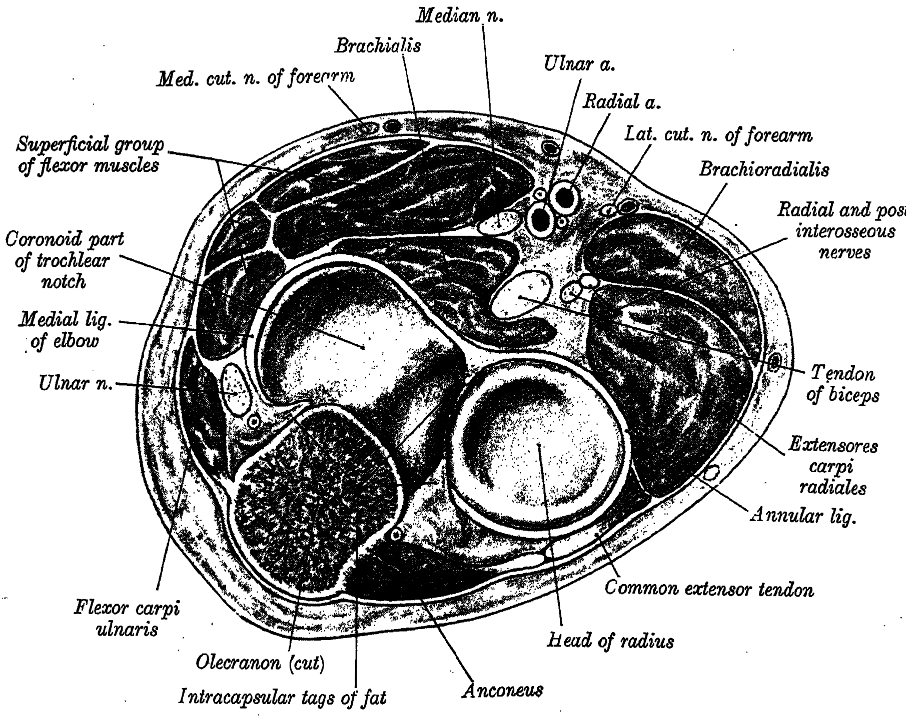
Fig. 532.—The left elbow-joint. Viewed from the lateral side.



Movements.—The elbow is a hinge-joint and therefore its movements consist of flexion and extension, the ulna moving on the trochlea, and the head of the radius on the capitulum of the humerus ; as the part of the capitulum which covers the inferior surface of the lower end of the humerus is smaller than the head of the radius, the posterior edge of the head of the radius can be felt projecting at the back of the joint when the forearm is fully extended. The movement of extension is limited by the tension of the ligaments and muscles on the front of the joint ; that of flexion chiefly by the tension of the structures on the back of the joint.

When the forearm is fully extended and the hand supinated, the upper arm and forearm are not in the same line ; the forearm is directed somewhat laterally, and forms with the upper arm an angle of about 167° in the female and 173° in the male. This 'carrying angle' is caused partly by the medial edge

FIG. 533.—Transverse section of the right elbow-joint, viewed from above, to show the relations of the joint.



of the trochlea of the humerus, which projects about 6 mm. below the lateral edge,* and partly by the obliquity of the superior articular surface of the coronoid process, which is not set at right angles to the shaft of the ulna. The angles which the articular surfaces of the humerus and the ulna make with the long axes of the bones are approximately equal, and as a result the carrying angle disappears on full flexion of the forearm and the two bones come to lie in the same plane. When this movement is carried out with the arm by the side, the ulnar border of the little finger lies over the clavicle on account of the position of the resting humerus (p. 346). If the humerus is rotated laterally during the movement, the hand is carried upwards in front of the shoulder. The carrying angle is masked also in pronation of the extended forearm, and this has the effect of bringing the upper arm, the semipronated forearm and the hand into the same straight line. This arrangement increases the precision with which the hand, and any instrument or weapon held in the hand, can be controlled in full extension of the elbow or while the elbow is being extended.

* Consult articles by H. Percy Potter (*Journal of Anatomy and Physiology*, vol. xix. p. 488), and A. Ralph Thompson (*Journal of Anatomy*, vol. lviii. p. 368).

The *accessory movements* of the elbow joint are very limited in range and are restricted to abduction and adduction of the ulna, and forward and backward movement of the head of the radius on the capitulum of the humerus. In the latter movement, the head of the radius is moved on the radial notch of the ulna also, the annular ligament being slewed backwards and forwards at the same time. The extent of this movement is greatest when the elbow-joint is half-flexed.

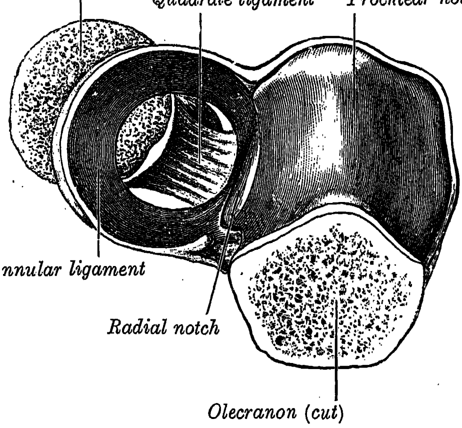
V. THE RADIO-ULNAR JOINTS

The radius and the ulna are connected at their upper and lower extremities by synovial joints, termed the superior and inferior radio-ulnar joints. In addition, the shafts of the bones are connected by an interosseous membrane and a ligament, which together constitute a middle radio-ulnar union.

1. The Superior Radio-ulnar Joint

This articulation forms a pivot-joint between the circumference of the head of the radius and the osseofibrous ring formed by the radial notch of the ulna and the annular ligament.

Fig. 534.—The annular ligament of the left radius. Superior aspect. The head of the radius has been sawn off and the bone dislodged from the ligament.



The **annular ligament** (figs. 532, 533, 534) is a strong band which encircles the head of the radius, and retains it in contact with the radial notch of the ulna. It forms about four-fifths of the osseofibrous ring and is attached to the anterior and posterior margins of the radial notch ; a few of its lower fibres are continued round below the notch and form at this level a complete fibrous ring. Its upper border blends with the lateral, anterior and posterior ligaments of the elbow-joint, while from its lower border a thin loose membrane passes to be attached to the neck of the radius. A few fibres extend from the inferior border of the radial notch to the neck of the radius, covering the synovial membrane which closes the distal aspect of the joint. They constitute the *quadrate ligament*. The *superficial surface* of the annular ligament is strengthened by the lateral ligament of the elbow, and affords origin to part of the supinator. It is related posteriorly to the anconeus and the posterior interosseous recurrent artery. On its *inner surface* the annular ligament is provided with a thin coating of cartilage where it comes into contact with the circumference of the head of the radius ; its lower part is lined with synovial membrane which is reflected upwards on to the neck of the bone.

2. The Middle Radio-ulnar Union

The shafts of the radius and ulna are connected by the oblique cord and the interosseous membrane of the forearm.

The **oblique cord** (fig. 531) is a small, flattened band, extending from the lateral side of the tuberosity of the ulna to the radius a little below the radial tuberosity. Its fibres run at right angles to those of the interosseous membrane. It is sometimes wanting.

The **interosseous membrane of the forearm** is a broad and thin sheet, the fibres of which slant obliquely downwards and medially from the interosseous border of the radius to that of the ulna; the lower part of the membrane is attached to the posterior of the two lines into which the interosseous border of the radius divides. Two or three bands are occasionally found on the posterior surface of this membrane; their fibres descend obliquely from the ulna towards the radius, i.e. at right angles to the other fibres. The membrane is deficient above, commencing about 2 or 3 cm. below the tuberosity of the radius; is broader in the middle than at either end; and presents an oval aperture a little above its lower margin, for the passage of the anterior interosseous vessels to the back of the forearm. Between its upper border and the oblique cord there is a gap, through which the posterior interosseous vessels pass. The membrane connects the bones, and increases the extent of surface for the attachment of the deep muscles of the forearm. It also transmits to the ulna and thence to the humerus any force acting upwards through the hand and radius. It is relaxed in complete pronation or supination, and is tense when the hand is midway between the prone and supine positions. *In front* the membrane is in relation, in its upper three-fourths, with the flexor pollicis longus on the radial side, with the flexor digitorum profundus on the ulnar side and between these muscles with the anterior interosseous vessels and nerve; in its lower one-fourth with the pronator quadratus; *behind*, with the supinator, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, extensor indicis; and, near the wrist, with the anterior interosseous artery and posterior interosseous nerve.

3. The Inferior Radio-ulnar Joint

This is a pivot-joint formed between the head of the ulna and the ulnar notch of the lower end of the radius; the surfaces are enclosed in a capsular ligament and held together by an articular disc.

The capsular ligament is slightly thickened in front and behind; above it is lax, and, lined with the synovial membrane, projects upwards as a pouch (*recessus sacciformis*) in front of the lower part of the interosseous membrane.

The **articular disc** (fig. 537), triangular in shape, binds the lower ends of the ulna and radius together. Its periphery is thicker than its centre, which is occasionally perforated. It is attached by its apex to a depression between the styloid process and the inferior surface of the head of the ulna; and by its base, which is thin, to the prominent edge which separates the ulnar notch from the carpal articular surface of the radius. Its margins are united to the ligaments of the wrist-joint. Its *upper surface*, smooth and concave, articulates with the head of the ulna. Its *lower surface*, also smooth and concave, forms a part of the radiocarpal joint and articulates with the medial part of the lunate bone; when the hand is adducted, it articulates with the triquetral bone. Each of its surfaces is clothed with synovial membrane: the upper, with that of the inferior radio-ulnar articulation; the lower, with that of the radiocarpal joint.

Movements.—The movements which take place at the radio-ulnar joints result in pronation and supination of the hand. In *pronation* the radius, carrying the hand with it, is carried obliquely across the front of the ulna, its upper end being lateral, and its lower end medial, to that bone. If the forearm is semiflexed when this movement occurs, the palm of the hand faces downwards and slightly medially; if the forearm is extended, the palm faces backwards and slightly medially. In *supination* the movement is reversed, the radius lies lateral to and parallel with the ulna, and the palm faces upwards—forwards if

the forearm is extended. When the humerus is fixed and the movement is limited to the radio-ulnar joints, the hand can be turned through an angle of 160°-170°, but under normal conditions the range of the movement is very greatly increased by rotation of the humerus. The power of supination is greater than that of pronation, and thus all screw-driving instruments are made to be used in this movement.

The axis on which these movements take place is represented by a line drawn through the centre of the head of the radius above, and through the ulnar attachment of the articular disc below. The head of the radius rotates within the ring formed by the annular ligament and the radial notch of the ulna, while the lower end and the articular disc revolve on the head of the ulna. The lower end of the ulna is not stationary during these movements. It moves backwards and laterally during pronation, and forwards and medially during supination, but the range of the movement is very small and is due to the incongruence of the trochlea and trochlear notch, already noted (p. 463). It does not involve any true rotation of the ulna.

Accessory movements.—In addition to the backward and forward movement of the head of the radius on the radial notch of the ulna (p. 468), the head of the ulna can be moved backwards and forwards on the ulnar notch of the radius.

Muscles producing the movements.—These muscles may be grouped as (*a*) those acting on the elbow-joint, and (*b*) those acting on the radio-ulnar joints.

(*a*) **Muscles acting on the elbow-joint :**

In **flexion**, the *brachialis, biceps* and *brachioradialis* are the prime movers, but, owing to the position of its attachments, the brachioradialis acts to best advantage when the forearm is in the midprone position. When resistance is encountered additional help is given by the *pronator teres* and the radial extensors of the wrist.

Extension is performed by the *triceps* and *anconeus.*

(*b*) **Muscles acting on the radio-ulnar joints:**

In **pronation**, the *pronator teres* and *pronator quadratus* are the prime movers, but, in order to overcome resistance, the palmaris longus and the flexor carpi radialis may be called into play, and the brachioradialis is capable of assisting from the position of full supination to the midprone position.

In **supination**, the *supinator* is the principal agent, but *biceps* is a powerful factor when the elbow is flexed, and the brachioradialis, from the fully prone to the midprone position, and the extensors of the thumb are capable of participating in the movement.

Applied Anatomy.—Dislocations backwards and abduction dislocations are the commonest forms of dislocation at the elbow-joint. Owing to the shapes of the bones, dislocation backwards is often complicated by fracture of the coronoid process; and, owing to the strength of the collateral ligaments, the medial epicondyle is frequently torn away in abduction dislocations. Dislocation of the elbow-joint is common in children. In lesions of this joint it is often difficult to ascertain the exact nature of the injury except by *x*-ray examination.

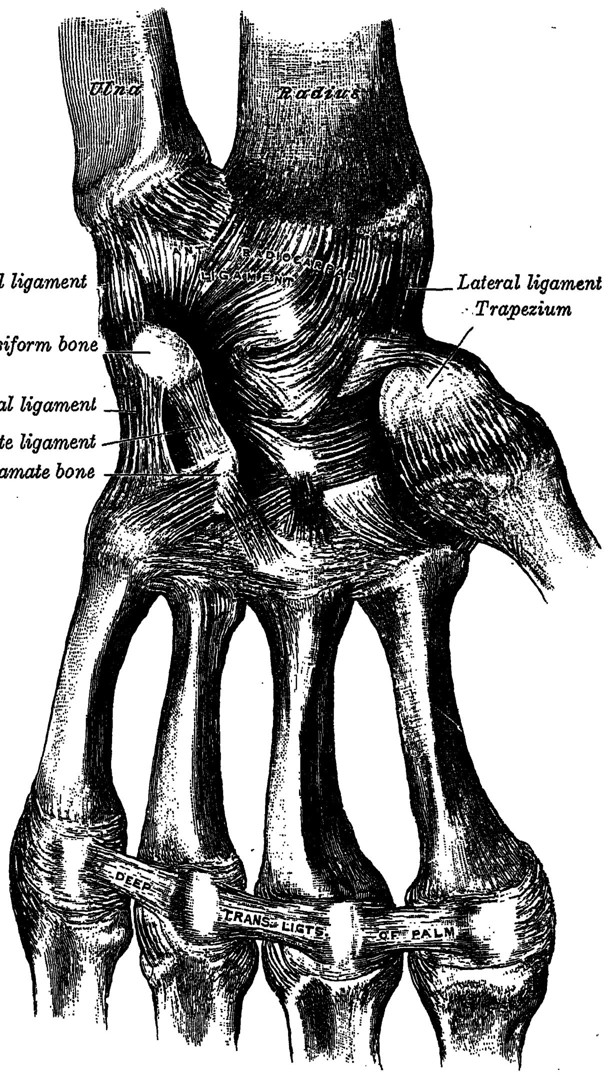
The elbow-joint is occasionally the seat of acute synovitis. The joint-cavity then becomes distended with fluid, the bulging showing itself principally around the olecranon, in consequence of the laxness of the articular capsule. Again, there is often some swelling, just above the head of the radius, in the line of the humeroradial joint, or the whole elbow may assume a fusiform appearance.

Dislocation of the head of the radius alone is a not uncommon accident, and occurs most frequently in young persons from falls on the hand when the forearm is extended and supinated, the head of the bone being displaced forward. It is attended by rupture of the annular ligament. Occasionally a peculiar injury, which is supposed to be a subluxation, occurs in young children. It is believed that the head of the radius is displaced downwards in the annular ligament, the upper border of which becomes folded over the head of the radius, between it and the capitulum of the humerus; the small size of the head of the radius in the child predisposes to this injury. The forearm becomes fixed in a position of semiflexion, midway between supination and pronation, and great pain is complained of when any attempt is made to move the joint.

VI. THE RADIOCARPAL OR WRIST-JOINT

The radiocarpal or wrist-joint (figs. 535-537) is a condyloid joint. The parts forming it are the distal end of the radius and lower surface of the articular disc, above; and the scaphoid, lunate, and triquetral bones, below. The *articular surface* of the radius and the lower surface of the articular disc form

FIG. 535.—The ligaments of the left wrist and metacarpus. Palmar aspect.



together a transversely elliptical, concave surface—the *receiving cavity*. The proximal articular surfaces of the scaphoid, lunate, and triquetral bones form a smooth convex surface, which is received into the concavity. The joint is surrounded by an articular capsule. The *synovial membrane* is usually distinct from that of the inferior radio-ulnar joint and from that of the carpal joints; the *capsular ligament* is strengthened by the following ligaments:

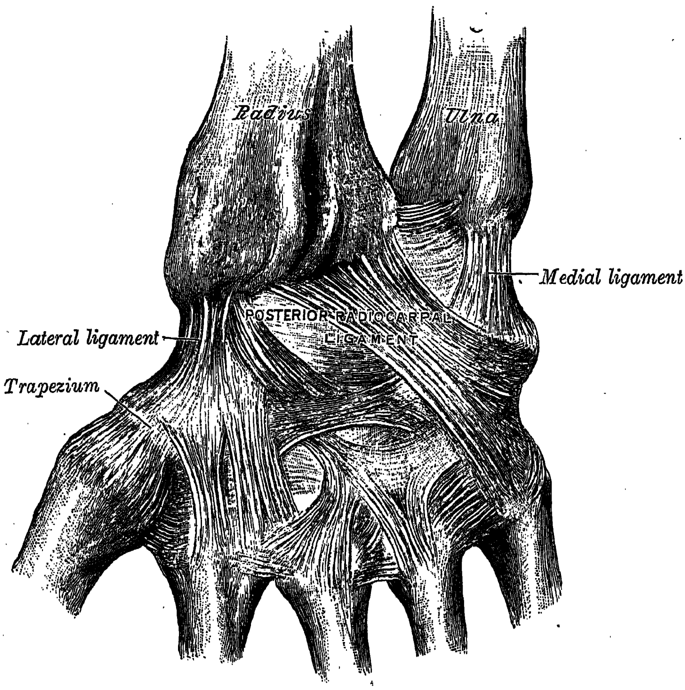
Anterior and posterior radiocarpal. Medial and lateral.

The **anterior radiocarpal ligament** (fig. 535) is a broad membranous band, attached above to the anterior margin of the lower end of the radius, to its styloid process, and to the front of the lower end of the ulna; its fibres pass

downwards and medially to be attached to the anterior surfaces of the scaphoid, lunate, and triquetral bones, some being continued to the capitate bone. In addition to this broad membrane, there is a rounded fasciculus, superficial to the rest, which reaches from the base of the styloid process of the ulna to the lunate and triquetral bones. The ligament is perforated by apertures for the passage of vessels, and is in relation, in front, with the tendons of the flexor digitorum profundus and flexor pollicis longus ; behind, it is closely adherent to the anterior border of the articular disc of the inferior radio-ulnar articulation.

The **posterior radiocarpal ligament** (fig. 536), thinner and weaker than the anterior, is attached, above, to the posterior border of the distal end of the radius ; its fibres are directed obliquely downwards and medially, and are fixed,

FIG. 536.—The ligaments of the left wrist. Posterior aspect.



below, to the posterior surfaces of the scaphoid, lunate, and triquetral bones, being continuous with those of the dorsal intercarpal ligaments. It is in relation, behind, with the extensor tendons of the wrist and fingers, their synovial sheaths and the posterior interosseous nerve ; in front, it is blended with the articular disc of the inferior radio-ulnar articulation.

The **medial (ulnar collateral) ligament** of the wrist-joint (figs. 535, 536) is attached to the end of the styloid process of the ulna ; it divides into two fasciculi, one of which is fixed to the medial side of the triquetral bone, the other to the pisiform bone.

The **lateral (radial collateral) ligament** of the wrist-joint (figs. 535, 536) extends from the tip of the styloid process of the radius to the radial side of the scaphoid bone, some of its fibres being prolonged to the trapezium (greater multangular bone). It is in relation with the radial artery, which separates the ligament from the tendons of the abductor pollicis longus and extensor pollicis brevis.

The *arteries* supplying the joint are the anterior interosseous, the anterior and posterior carpal branches of the radial and ulnar, the palmar and dorsal metacarpals, and some recurrent branches from the deep palmar arch. The *nerves* are derived from the anterior and posterior interosseous nerves.

Movements.—The active movements which can be carried out at this joint are flexion, extension, abduction, adduction, and circumduction. Flexion and extension are the most free, and of these a greater amount of extension than of

flexion is permitted, and in consequence the articulating surfaces extend farther on the posterior than on the anterior surfaces of the carpal bones. In this movement the carpal bones rotate on a transverse axis drawn between the tips of the styloid processes of the radius and ulna. The movements of flexion and extension are limited chiefly by the tension of the antagonistic muscles, and it is only when the joint is subjected to violent movement that the anterior or posterior ligament is fully stretched. In this connexion it should be noted that the range of flexion is perceptibly diminished when the fingers are flexed, owing to increased tension of the extensor muscles. Adduction or ulnar deviation, and abduction or radial deviation are also permitted. The former is considerably greater in extent than the latter, and this fact may be associated with the shortness of the styloid process of the ulna. The movements are limited by the tension of the antagonistic muscles, and in addition by the lateral and medial ligaments of the joint respectively. In this movement the carpus revolves upon an anteroposterior axis drawn through the centre of the wrist. Finally, circumduction is permitted by the combined and consecutive movements of adduction, extension, abduction and flexion. The effect of rotation is obtained by the pronation and supination of the radius on the ulna.

The *accessory movements* which can be carried out at the wrist-joint are relatively free and are more so in flexion than in extension. The carpus can be moved bodily backwards and forwards on the radius and ulna, and it can be rotated to a considerable extent. A little side to side movement can also be obtained.

Muscles producing the movements :

In **flexion,** the *flexor carpi radialis, flexor carpi ulnaris* and *palmaris longus* are the principal agents, but the flexores digitorum sublimis et profundus and the flexor pollicis longus are capable of giving assistance.

In **extension,** the *extensores carpi radialis longus et brevis,* and *extensor carpi ulnaris* are the chief muscles concerned, but the extensors of the fingers and thumb are all capable of helping.

In **adduction,** the *flexor carpi ulnaris* acts in association with the *extensor carpi ulnaris,* and in **abduction** the *flexor carpi radialis* acts in association with the *extensores carpi radialis longus et brevis,* the abductor pollicis longus and the extensor pollicis brevis. As a result of these combinations the movements can be carried out without the simultaneous occurrence of flexion or extension.

VII. THE INTERCARPAL JOINTS

The intercarpal joints connect the carpal bones to one another and may be subdivided into: (1) joints between the bones of the proximal row of the carpus; (2) joints between the bones of the distal row; and (3) a somewhat complicated and extensive joint between the two rows. Only a very slight degree of gliding movement is allowed between contiguous bones in the same row, and these joints are all of the plane variety, but a somewhat wider range of movement is allowed at the joint between the two rows, which, in its medial part at least, approaches nearer to the condyloid variety than to the plane variety of joint.

1. The Joints of the Proximal Row of Carpal Bones

The scaphoid, lunate and triquetral bones are connected by dorsal, palmar and interosseous ligaments.

The **dorsal and palmar ligaments** are placed transversely between the bones of the first row; they connect the scaphoid bone to the lunate and the lunate bone to the triquetral. The palmar ligaments are weaker than the dorsal.

The **interosseous ligaments** (fig. 537) are two narrow bundles, one connecting the lunate and scaphoid bones, the other the lunate and triquetral bones. They are on a level with the proximal surfaces of these bones, and form part of the convex articular surface of the radiocarpal joint.

The pisiform bone articulates with the palmar surface of the triquetral bone, and the ligaments of the joint are: a capsular, a pisohamate and a pisometacarpal ligament.

The **capsular ligament** is thin, and surrounds the joint; *its synovial membrane is distinct from that of the other carpal joints.*

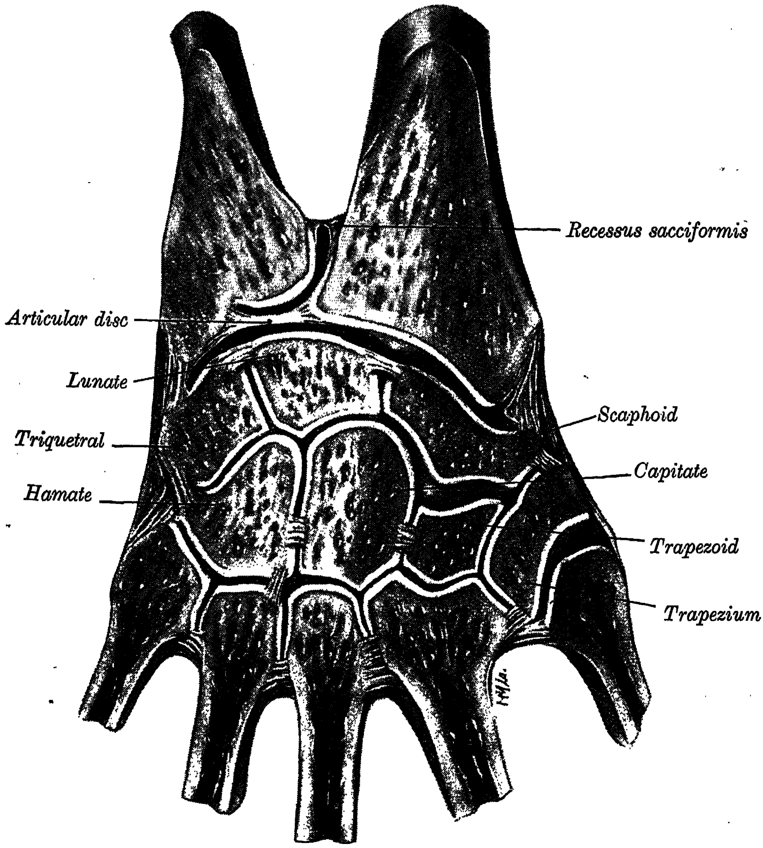
The **pisohamate ligament** connects the pisiform to the hook of the hamate bone, and the **pisometacarpal ligament** joins the pisiform to the base of the fifth metacarpal bone (fig. 535). Both ligaments are continuous with the tendon of insertion of the flexor carpi ulnaris.

2. The Joints of the Distal Row of Carpal Bones

The bones of the distal row of the carpus are connected by the dorsal, palmar and interosseous ligaments.

The **dorsal** and **palmar ligaments** extend transversely from one bone to

Fig. 537.—A coronal section through the joints at the right wrist, showing the synovial cavities.



another; one of each connects the trapezium and trapezoid (greater and lesser multangular) bones, a second the trapezoid bone and the capitate, and a third the capitate bone and the hamate.

The three **interosseous ligaments** are much thicker than those of the proximal row; one unites the capitate bone and the hamate, a second the capitate bone and the trapezoid, and a third the trapezium and trapezoid. The first is the strongest; the third is sometimes wanting.

3. The Joints of the Two Rows of Carpal Bones with each other

The joint between the scaphoid, lunate and triquetral bones on the one hand, and the second row of carpal bones on the other, is named the *mid-carpal joint,* and is made up of two portions: on the medial side the head of the capitate bone and the hamate bone articulate with the concavity formed by the scaphoid, lunate and triquetral bones, and constitute a modified condyloid

joint; on the lateral side the trapezium and trapezoid articulate with the scaphoid bone and constitute a modified plane joint.

The ligaments are: dorsal, palmar, medial and lateral.

The **dorsal and palmar ligaments** consist of short, irregular bundles passing between the bones of the first and second rows. On the palmar surface the fibres radiating from the head of the capitate bone to the surrounding bones are sometimes termed the *ligamentum carpi radiatum.*

The **lateral and medial ligaments** are very short: the one is placed on the radial, the other on the ulnar side of the carpus: the former, the stronger and more distinct, connects the scaphoid bone and the trapezium, the latter the triquetral bone and the hamate; they are continuous with the corresponding ligaments of the wrist-joint. In addition to these ligaments, a slender, interosseous band sometimes connects the capitate and scaphoid bones.

The **synovial membrane of the carpus** is very extensive (fig. 537), and bounds a cavity of very irregular shape. The proximal part of the cavity intervenes between the distal surfaces of the scaphoid, lunate and triquetral bones and the proximal surfaces of the bones of the second row. It sends two prolongations upwards—between the scaphoid and lunate bones, and between the lunate and triquetral bones—and three downwards between the four bones of the second row. The prolongation between the trapezium and the trapezoid, or that between the trapezoid and capitate bone, is, owing to the absence of the interosseous ligament, often continuous with the cavity of the carpometacarpal joints, sometimes of the second, third, fourth, and fifth metacarpal bones, sometimes of the second and third only. In the latter condition the joint between the hamate bone and the fourth and fifth metacarpal bones has a separate synovial membrane and is separated from the others (fig. 537) by the medial carpometacarpal interosseous ligament (p. 476). The synovial cavities of the carpometacarpal joints are prolonged for a short distance between the bases of the metacarpal bones. There is a separate synovial cavity between the pisiform and triquetral bones.

Movements.—The chief movements permitted in the mid-carpal joint are flexion and extension, flexion being freer than extension. A very slight amount of abduction and adduction is also permitted, the head of the capitate bone rotating round an anteroposterior axis drawn through its own centre. These movements cannot be performed actively except in association with corresponding movements of the wrist and fingers. They may therefore be regarded as *accessory movements* of the first type (p. 431).

VIII. THE CARPOMETACARPAL JOINTS

1. The Carpometacarpal Joint of the Thumb

This is a saddle-shaped joint between the base of the first metacarpal bone and the trapezium (greater multangular bone), and it enjoys great freedom of movement on account of the configuration of its articular surfaces. The joint is surrounded by a **capsular ligament**, which is thick but loose, and passes from the circumference of the base of the metacarpal bone to the rough edge bounding the articular surface of the trapezium; it is thickest laterally and dorsally. *The synovial membrane which lines the capsular ligament is distinct from that of the other carpometacarpal joints* (fig. 537).

Movements.—In this articulation the movements permitted are flexion combined with opposition, extension, abduction, adduction and circumduction. Flexion and extension take place in the plane of the palm of the hand; abduction and adduction at right angles to this plane (p. 430). Owing to the shapes of the articular surfaces concerned, flexion at this joint is not a simple movement but is accompanied by a slight degree of medial rotation of the metacarpal bone of the thumb, which enables the tip of the thumb to be brought into contact with the palmar aspects of the tips of the slightly flexed fingers. This movement is termed opposition but it cannot be dissociated from flexion and, conversely, flexion at this joint always involves the slight rotatory movement which makes opposition possible.

No *accessory movements* can be obtained at this joint with the exception of separation of the two bones; this can be effected by traction.

Muscles producing the movements :

Flexion and Opposition.—Opponens pollicis, Flexores pollicis longus et brevis.

Extension.—Extensores pollicis longus et brevis.

Adduction.—Adductor pollicis.

Abduction.—Abductores pollicis brevis et longus.

2. The Joints of the Second, Third, Fourth and Fifth Metacarpal Bones with the Carpus

The joints between the carpus and the second, third, fourth, and fifth metacarpal bones are plane joints. The bones are united by **capsular ligaments,** strengthened by dorsal, palmar and interosseous ligaments.

The **dorsal ligaments,** the strongest and most distinct, connect the carpal and metacarpal bones on their dorsal surfaces. The second metacarpal bone receives two fasciculi, one each from the trapezium and trapezoid (greater and lesser multangular) bones ; the third metacarpal receives two, one each from the trapezoid and capitate bones ; the fourth two, one each from the capitate and hamate bones ; the fifth receives a single fasciculus from the hamate bone, and this is continuous with a similar ligament on the palmar surface, forming an incomplete capsular ligament.

The **palmar ligaments** have a somewhat similar arrangement, with the exception of those of the third metacarpal bone, which are three in number : a lateral one from the trapezium (greater multangular bone), situated superficially to the sheath of the tendon of the flexor carpi radialis ; an intermediate one from the capitate bone ; and a medial one from the hamate bone.

The **interosseous ligaments** consist of short, thick fibres, and are limited to one part of the carpometacarpal articulation ; they connect the contiguous inferior margins of the capitate and hamate bones with the adjacent surfaces of the third and fourth metacarpal bones, and they may be united at their proximal ends.

The **synovial membrane** is a continuation of that of the intercarpal joints. Occasionally, the joint between the hamate bone and the fourth and fifth metacarpal bones has a separate synovial membrane, and is then bounded on its lateral side by the more medial of the two interosseous ligaments, just described, and extensions from it to the palmar and dorsal parts of the capsule (fig. 537).

Movements.—The movements permitted in the carpometacarpal articulations of the fingers are limited to slight gliding of the articular surfaces upon each other, the extent of which varies in the different joints. They are really accessory movements of the first type. The metacarpal bone of the little finger is the most movable, then that of the ring-finger ; the metacarpal bones of the index and middle fingers are almost immovable.

The *accessory movements* are limited to spiral twisting of the metacarpus as a whole on the carpus.

IX. THE INTERMETACARPAL JOINTS

The bases of the second, third, fourth and fifth metacarpal bones articulate with one another by small surfaces covered with cartilage, and are connected together by dorsal, palmar and interosseous ligaments.

The **dorsal and palmar ligaments** pass transversely from one bone to another on the dorsal and palmar surfaces. The **interosseous ligaments** connect the contiguous surfaces of the bones, just distal to their collateral articular facets.

The **synovial membrane** of these joints is continuous with that of the carpometacarpal articulations.

X. THE METACARPOPHALANGEAL JOINTS

These articulations (figs. 538, 539) are of the condyloid variety and are formed by the reception of the rounded heads of the metacarpal bones into

shallow cavities on the bases of the proximal phalanges. The metacarpophalangeal joint of the thumb is somewhat exceptional, for its movements of flexion and extension seldom exceed 60° and its side to side movements are very much restricted. Each joint has a palmar and two collateral ligaments.

The **palmar ligaments** (accessory volar ligaments) are thick, dense, fibrocartilaginous structures, placed upon the palmar surfaces of the joints in the

Fig. 538.—The metacarpophalangeal and digital joints. Palmar aspect.

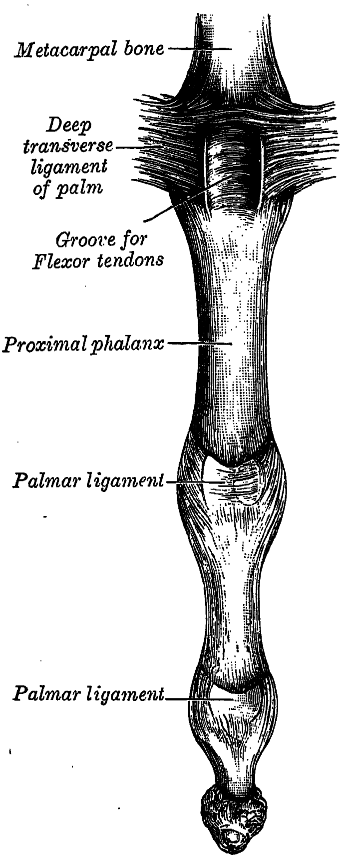
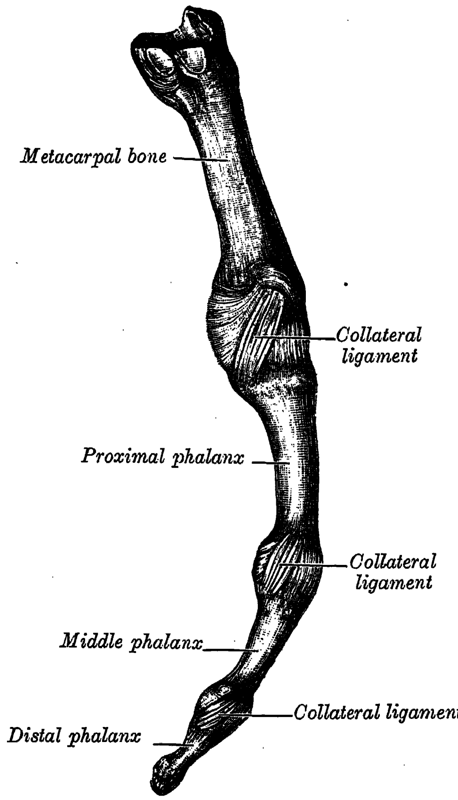


Fig. 539.—The metacarpophalangeal and digital joints. Medial aspect.



intervals between the collateral ligaments, to which they are connected; they are loosely united to the metacarpal bones, but are very firmly attached to the bases of the proximal phalanges. Their palmar surfaces are intimately blended with the deep transverse ligaments of the palm, and grooved for the flexor tendons, the fibrous sheaths of which are connected to the sides of the grooves. Their deep surfaces form parts of the articular areas for the heads of the metacarpal bones.

The **deep transverse ligaments of the palm** consist of three short, wide, flattened bands which connect the palmar ligaments of the second, third, fourth and fifth metacarpophalangeal joints to one another (fig. 538). They are related, anteriorly, to the lumbrical muscles and the digital vessels and nerves and, posteriorly, to the interosseous muscles. Offsets from the digital slips of the central portion of the palmar aponeurosis join the palmar surface (p. 614).

The **collateral ligaments** are strong, rounded cords, placed on the sides of the joints; each is attached to the posterior tubercle and adjacent depression on the side of the head of the metacarpal bone, and passes downwards and forwards to reach the side of the base of the phalanx (fig. 539).

The dorsal surfaces of these joints are covered with the expansions of the extensor tendons, together with some loose areolar tissue which connects the deep surfaces of the tendons to the bones.*

Movements.—The active movements which occur in these joints are flexion, extension, adduction, abduction, and circumduction.

Flexion is freer than extension, and both movements are limited by the tension of the opposing muscles. Abduction and adduction are less free and cannot be performed actively when the fingers are flexed (*vide infra*).

The *accessory movements* comprise rotation (which in the case of the thumb may be considerable) and gliding of the phalanx on the head of the metacarpal bone forwards, backwards and from side to side. In addition the articular surfaces can be separated by traction.

Muscles producing the movements :

In **flexion,** the *flexores digitorum sublimis et profundus* are assisted by the *lumbricals* and the interossei (p. 619) and, in the case of the little finger, by the *flexor digiti minimi.* In the thumb, the *flexores pollicis longus et brevis* are assisted by the first *palmar interosseous muscle.*

In **extension** of the middle and ring fingers at the metacarpophalangeal joints, the *extensor digitorum* is the only muscle concerned, but the *extensor indicis* and the *extensor digiti minimi* take part in extension of the index and little fingers, respectively. In the thumb the *extensores pollicis longus et brevis* are the only muscles concerned.

Adduction of the extended fingers is performed by the *palmar interossei,* but during flexion the long flexors of the fingers play the principal part. The slight degree of this movement in the thumb is attributable to the *adductor pollicis* and the *first palmar interosseous muscle.*

Abduction of the extended fingers is performed by the *dorsal interossei* assisted by the *long extensors.* In the little finger the *abductor digiti minimi* is the principal agent, and the *abductor pollicis brevis* produces the slight movement possible in the thumb. When the fingers are in the flexed position, abduction cannot be performed actively, but, provided that the long flexors of the fingers are not in active contraction, it can easily be carried out passively. The inability to perform the movement actively in this position is presumably due to the fact that the dorsal interossei and the abductor digiti minimi are so relaxed by flexion that they are unable to function ; the inability is certainly not to be ascribed to tension of the collateral ligaments.

XI. THE DIGITAL JOINTS (figs. 538, 539)

The digital or interphalangeal articulations are hinge-joints, and each has a palmar and two collateral ligaments. The arrangement of these ligaments is similar to those in the metacarpophalangeal joints (p. 477). The extensor tendons supply the places of dorsal ligaments.

Movements.—The only active movements which occur at the interphalangeal joints are flexion and extension ; these movements are freer between the proximal and middle phalanges than between the middle and distal. The amount of flexion is very considerable, but extension is limited by tension of the digital flexors and, in violent movements, by the palmar ligaments.

The *accessory movements* comprise a limited range in each case of rotation, abduction, adduction and gliding forwards and backwards. They permit the fingers to adapt themselves to the shape of any object gripped in the hand, and they provide against the stresses and strains which occur during the ordinary use of the hand.

Muscles producing the movements :

In **flexion** of the proximal joint both the flexor digitorum sublimis and the flexor digitorum profundus are concerned ; in the distal joint, the latter muscle is the sole agent. At the interphalangeal joint of the thumb, the *flexor pollicis longus* is the only muscle available.

* Consult an article on "The Nerve Supply of the Interphalangeal and Metacarpophalangeal joints," by J. S. B. Stopford, *Journal of Anatomy,* vol. lvi. 1921.

In **extension**, which takes place simultaneously at both joints, the *lumbricals* and the *interossei*, both palmar and dorsal, are the active agents, owing to their insertion into the expansion of the extensor tendon (p. 619). The extensor digitorum does not take part in the movement, owing to its fixation at the base of the proximal phalanx. In the thumb, the *extensor pollicis longus* is the only muscle concerned.

Attention should be drawn at this point to the combined movements of flexion at the metacarpophalangeal joint and extension at the interphalangeal joints which are carried out simultaneously and are of such importance in the fine movements executed in writing, drawing, painting, etc. The *lumbricals* are the principal agents in producing the movements, and they are enabled to do so by virtue of their anterior relationship to the transverse axes of the metacarpophalangeal joints and their attachment to the extensor tendon distal to that joint. The interossei are unable to initiate the movement, but they help to steady the metacarpophalangeal joints and assist the movement as soon as the lumbricals have caused the necessary degree of flexion.

THE JOINTS OF THE PELVIS

I. THE SACRO-ILIAC JOINT

The sacro-iliac articulation is a synovial joint between the auricular surfaces of the sacrum and ilium. Although the joint is to be regarded as of the plane variety, the *articular surfaces* are not flat, but are marked by a number of irregular elevations and depressions. These irregularities fit in to one another and provide a locking device which restricts movements to a minimum in order to ensure stability, for the sacro-iliac joint interrupts the line of weight transmission from the vertebral column to the lower limb. This mechanism permits the body weight to be transmitted through the joint without causing tension of the ligaments. In the adult male a large number of short but strong bundles of fibres enter into the constitution of the sacro-iliac ligaments and, as a result, only a very small amount of anteroposterior rotatory movement is possible. In the female, after puberty, the range is appreciably greater and it is increased temporarily in the later months of pregnancy.* In the elderly it is usual to find that the joint cavity is at least partly obliterated by the presence of fibrous or fibrocartilaginous adhesions. The ligaments of the joints are :

Anterior sacro-iliac. Interosseous sacro-iliac.
Posterior sacro-iliac.

The **anterior sacro-iliac ligament** (fig. 540) covers the anterior and inferior surfaces of the joint and consists of numerous thin bands. The superior fibres of the ligament connect the ala of the sacrum to the adjoining part of the iliac fossa ; the inferior fibres are placed below the arcuate line, and unite the lateral parts of the three upper sacral vertebræ to the pre-auricular sulcus (p. 374) and adjacent part of the ilium.

The **interosseous sacro-iliac ligament** is very strong, and forms the chief bond of union between the two bones. It fills the irregular space immediately above and behind the joint-cavity (figs. 543, 544) and is covered by the posterior sacro-iliac ligament. It consists of bundles of short fibres which connect the iliac and sacral tuberosities.

The **posterior sacro-iliac ligament** is oblique in direction ; it connects the posterior superior iliac spine to the upper four transverse tubercles of the sacrum. Its lower fibres are long and partly blended with the upper end of the sacrotuberous ligament. Its upper fibres are short and nearly horizontal.

The Vertebropelvic Ligaments

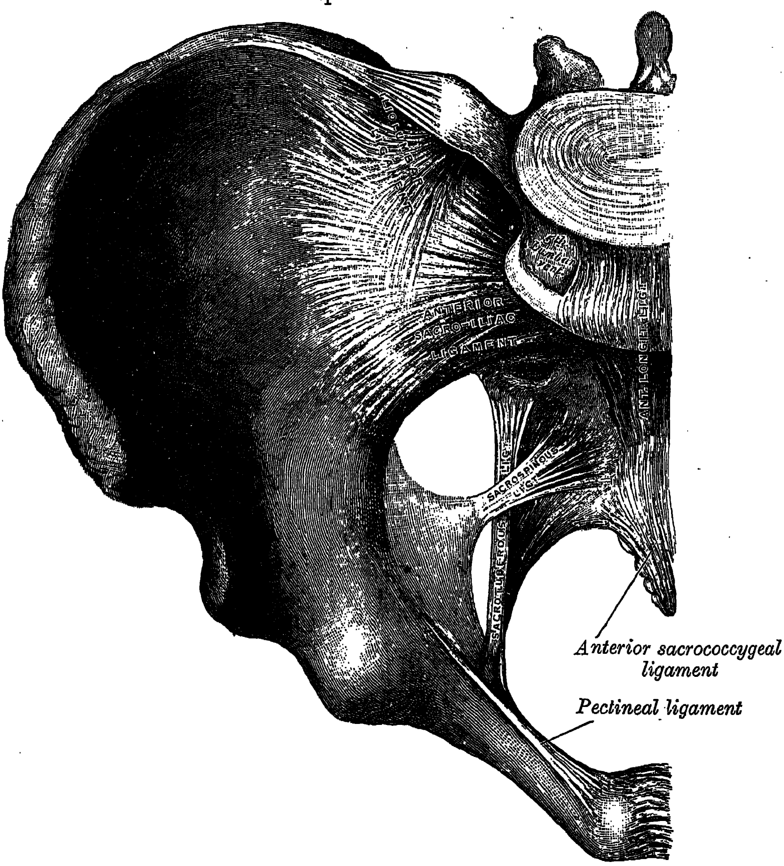
The ilium is connected to the fifth lumbar vertebra by the *iliolumbar ligament*, and the sacrum to the ischium by the *sacrotuberous* and *sacrospinous ligaments*.

* R. Brooke, *Journal of Anatomy*, 1924.

The **iliolumbar ligament** (fig. 540) is attached above to the lower and front part of the transverse process of the fifth lumbar vertebra, and occasionally has an additional, weak attachment to the transverse process of the fourth. It radiates as it passes laterally and is attached by two main bands to the pelvis. The lower band runs to the ala of the ilium and the base of the sacrum, blending with the anterior sacro-iliac ligament; the upper, which gives partial origin to the quadratus lumborum muscle, is attached to the crest of the ilium immediately in front of the sacro-iliac joint and is continuous above with the lumbar fascia.

The **sacrotuberous ligament** (figs. 540, 541) is placed at the lower and posterior part of the pelvis. It is attached by a broad base to the posterior

FIG. 540.—The joints and ligaments of the right side of the pelvis. Antero-superior aspect.



iliac spines (where it is partly blended with the posterior sacro-iliac ligament), to the third, fourth and fifth transverse tubercles of the sacrum, and to the lateral margin of the lower part of the sacrum and upper part of the coccyx. Its fibres run obliquely downwards and laterally, and converge to form a thick, narrow band; this band widens out below and is fixed to the medial margin of the ischial tuberosity, and is continued along the ramus of the ischium under the name of the *falciform process,* the free concave edge of which gives attachment to the fascia of the obturator internus muscle. On its posterior surface the ligament gives origin to the lowest fibres of the gluteus maximus, and some of the superficial fibres of its lower part are continued into the tendon of origin of the long head of the biceps femoris. The ligament is pierced by the coccygeal branches of the inferior gluteal artery, by the perforating cutaneous nerve and by minute filaments of the coccygeal plexus.

The **sacrospinous ligament** (fig. 540) is thin, and triangular in form; it is attached by its apex to the spine of the ischium, and, medially, by its broad

base, to the lateral margins of the sacrum and coccyx, in front of the sacrotuberous ligament, with which its fibres are intermingled. It is in relation in front with the coccygeus muscle, to which it is closely connected, and of which it may represent a degenerated part.

These two ligaments convert the sciatic notches into foramina. The *greater sciatic foramen* is bounded, in front and above, by the greater sciatic notch; behind by the sacrotuberous ligament; and below by the sacrospinous ligament and the spine of the ischium. It is partially filled up, in the recent state, by the piriformis muscle, which emerges from the pelvis through it. Above this muscle, the superior gluteal vessels and nerve pass out of the pelvis; and below it, the inferior gluteal vessels and nerve, the internal pudendal vessels and nerve, the sciatic and the posterior femoral cutaneous nerves, and the nerves to the obturator internus and quadratus femoris make their exit from the pelvis. The *lesser sciatic foramen* is bounded, in front, by the body of the ischium; above, by the

FIG. 541.—The joints and ligaments of the right side of the pelvis. Posterior aspect.

body of the ischium and the sacrospinous ligament; behind, by the sacrotuberous ligament. It transmits the tendon of the obturator internus, the nerve to this muscle, and the internal pudendal vessels and nerve.

The sacrotuberous and, to a lesser extent, the sacrospinous ligaments would oppose any tendency of the lower part of the sacrum to tilt upwards under the downward thrust which is imparted to the upper end of the bone by the weight of the trunk (p. 483).

II. THE PUBIC SYMPHYSIS (fig. 542)

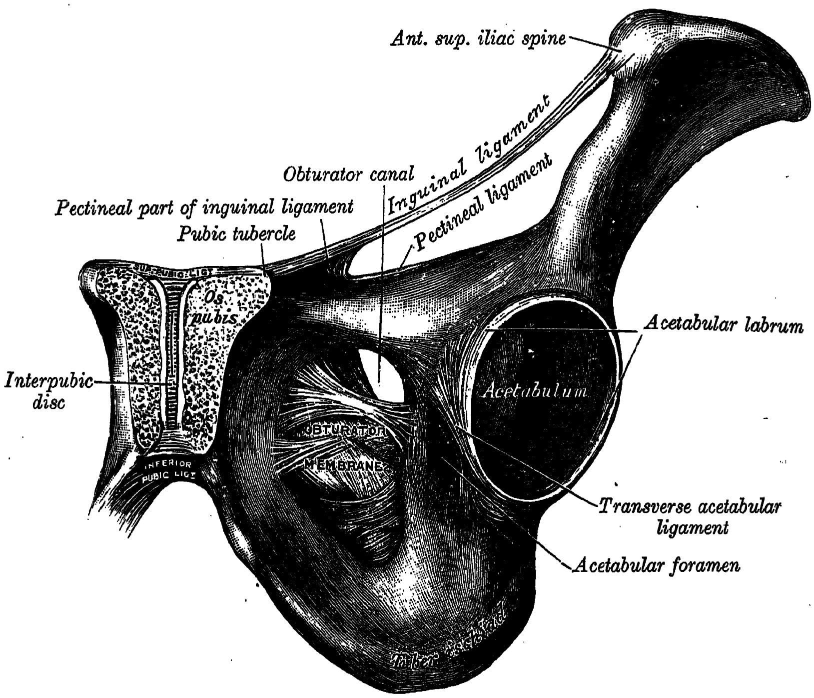
The pubic bones meet each other in the median plane, where they form a secondary cartilaginous joint which receives the special name of the pubic symphysis. The two bones are connected by a superior and an inferior pubic ligament, and by an interpubic disc of fibrocartilage.

The **superior pubic ligament** connects the pubic bones superiorly, and extends as far as the pubic tubercles.

The **inferior (arcuate) pubic ligament** is a thick, triangular arch of fibres, connecting the two pubic bones below, and forming the upper boundary of the pubic arch. Above, it is blended with the interpubic disc ; laterally, it is attached to the inferior rami of the pubic bones ; its base is free, and is separated from the perineal membrane (inferior fascia of the urogenital diaphragm) by an opening through which the deep dorsal vein of the penis (or clitoris) enters the pelvis.

The **interpubic disc** connects the opposed surfaces of the pubic bones. Each of these surfaces is covered with a thin layer of hyaline cartilage firmly joined

FIG. 542.—A coronal section through the pubic symphysis. Anterior aspect.



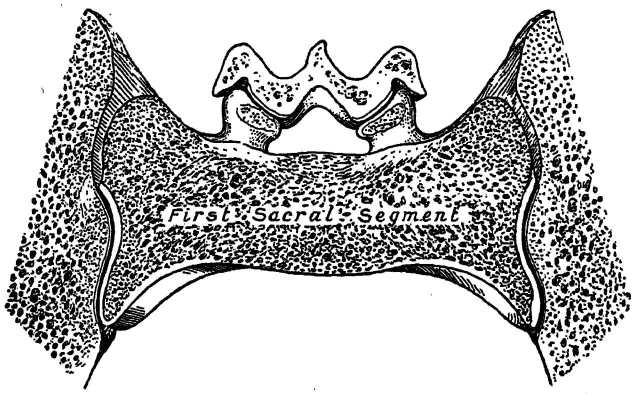
to the bone by a series of nipple-like processes which fit accurately into corresponding depressions on the osseous surface. These opposed cartilaginous surfaces are connected by a lamina of fibrocartilage, which varies in thickness in different subjects. It often contains a cavity in its interior, probably formed by the softening and absorption of the fibrocartilage, since it rarely appears before the tenth year of life and is not lined with synovial membrane. This cavity is usually limited to the upper and back part of the joint ; it occasionally reaches the front, and may extend the entire length of the cartilage. When present it may be demonstrated by making a coronal section of the symphysis pubis near its posterior surface (fig. 542). In front the disc is strengthened by several superimposed layers of fibres, which pass obliquely from one bone to the other, decussating and forming an interlacement with the fibres of the external oblique aponeuroses and the medial tendons of origin of the recti abdominis.

THE MECHANISM OF THE PELVIS

The pelvic girdle supports and protects the contained viscera and affords surfaces for the attachments of the muscles of the trunk and lower limb. Its most important mechanical function, however, is to transmit the weight of the trunk and upper limbs to the lower extremities.

It may be divided into two arches by a vertical plane passing through the acetabular cavities; the posterior of these arches is the one chiefly concerned in the function of transmitting the weight of the trunk. Its essential parts are the upper three sacral vertebræ and two strong pillars of bone running from the sacro-iliac joints to the acetabular fossæ (p. 378). The anterior of these arches is formed by the pubic bones and their superior rami. It connects the bases of the lateral pillars of the posterior arch and so acts as a tie-beam to prevent their separation and consequent collapse of the arch. The sacrum forms

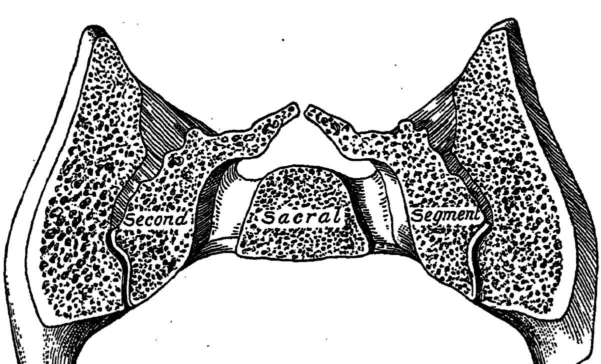
Fig. 543.—A coronal section through the anterior sacral segment.



the summit of the posterior arch; the weight transmitted falls on it at the lumbosacral joint and, theoretically, has a component in each of two directions. One component of the force is expended in driving the sacrum downwards and backwards between the iliac bones, while the other thrusts the upper end of the sacrum downwards and forwards towards the pelvic cavity.

The movements of the sacrum are regulated by its form. Viewed as a whole, it presents the shape of a wedge with its base upwards and forwards. The first component of the force is therefore acting against the resistance of the wedge,

Fig. 544.—A coronal section through the middle sacral segment.



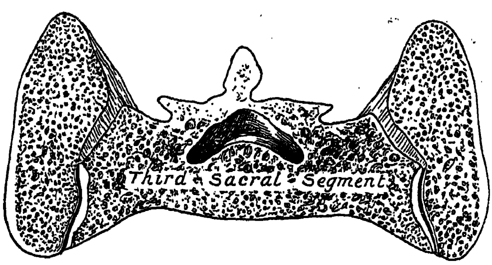
and its tendency to separate the iliac bones is resisted by the sacro-iliac and iliolumbar ligaments and by the ligaments of the symphysis pubis.

If a series of coronal sections be made through the sacro-iliac joints, it will be found possible to divide the articular portion of the sacrum into three segments: anterior, middle, and posterior. In the *anterior segment* (fig. 543), which involves the first sacral vertebra, the articular surfaces show slight sinuosities and are almost parallel to one another. In the *middle segment* (fig. 544) the width between the dorsal margins of the sacral articular surfaces is greater than that between the ventral margins, and in the centre of each surface there is a concavity into which a corresponding convexity of the iliac

articular surface fits. This forms an interlocking mechanism which prevents the strain of the body-weight from falling on the ligaments. In the *posterior segment* (fig. 545) the ventral width of the sacrum is greater than the dorsal, and the articular surfaces are only slightly concave.

Dislocation downwards and forwards of the sacrum by the second component of the force applied to it is prevented therefore by the middle segment, which interposes the resistance of its wedge-shape and that of the interlocking mechanism on its surfaces; a rotatory movement, however, is produced by which the anterior segment is tilted downwards and the posterior upwards: the axis of this rotation passes through the dorsal part of the middle segment. The movement of the anterior segment is slightly limited by its wedge-form, but chiefly by the posterior and interosseous sacro-iliac ligaments; that of the posterior segment is checked to a slight extent by its wedge-form, but the chief limiting factors are the sacrotuberous and sacrospinous ligaments. In all these movements the effect of the sacro-iliac and iliolumbar ligaments and the ligaments of the symphysis pubis in resisting the separation of the iliac bones must be recognised.

FIG. 545.—A coronal section through the posterior sacral segment.



Applied Anatomy.—During pregnancy the pelvic joints and ligaments are relaxed and capable therefore of more extensive movements. This relaxation of the ligaments renders the locking mechanism of the sacro-iliac joint less efficient and permits a rotation of the hip-bones to take place. This rotation has the effect of increasing the capacity of the pelvis. The less efficient the locking mechanism, the more the strain of weight bearing falls on the ligaments, leading to the frequent occurrence of sacro-iliac strain after pregnancy. During involution the ligaments become tightened up again and the locking mechanism is restored, but, in some cases, the locking may occur in the position of rotation of the hip-bones which was adopted during the pregnancy. This so-called subluxation of the sacro-iliac joint causes pain by the tension which it imposes on the ligaments, and reduction by forcible manipulation is required. The common position found in this condition is believed to be backward rotation of the hip-bone on the sacrum; it is usually unilateral.

THE JOINTS OF THE LOWER LIMB

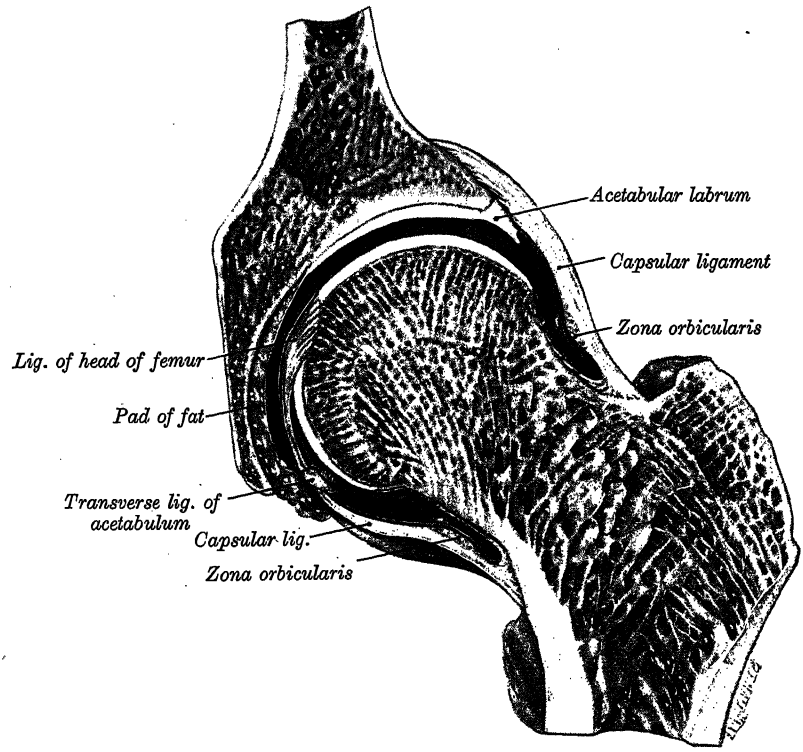
I. THE HIP-JOINT

The hip-joint is a ball-and-socket articulation, formed by the reception of the head of the femur into the cup-shaped fossa of the acetabulum. The *articular surfaces* are reciprocally and regularly curved, but are not co-extensive. The head of the femur is completely covered with articular cartilage, except over the small, roughened pit to which the ligament of the head is attached. In front, the cartilage extends laterally to cover a small area on the adjoining part of the neck of the femur. The cartilage is thickest at the centre of the head and thinner towards its periphery. The articular surface of the acetabulum forms an incomplete ring, broadest at its upper part where the pressure of the body weight falls in the erect attitude and narrowest where it covers the pubic constituent. The ring is deficient below opposite the acetabular notch. It is covered with articular cartilage which is thickest where the ring is broadest, but the floor of the acetabular fossa within the ring is devoid of articular cartilage and lodges a mass of fat covered with synovial membrane. The depth of the acetabulum is appreciably increased by a fibrocartilaginous rim, termed the *acetabular labrum*. The ligaments of the joint are:

The capsular.	Pubofemoral.
Iliofemoral.	Ligament of the head of the femur.
Ischiofemoral.	The acetabular labrum.
Transverse acetabular.	

The **capsular ligament** (figs. 548, 549) is strong and dense. Above, it is attached to the margin of the acetabulum, 5 or 6 mm. beyond the acetabular labrum ; in front, it is attached to the outer margin of the labrum, and, opposite the acetabular notch, to the transverse acetabular ligament and the edge of the obturator foramen. It surrounds the neck of the femur, and is attached in front to the trochanteric line ; above, to the base of the neck ; behind, to the neck about 1 cm. above the trochanteric crest ; below, to the lower part of the neck close to the lesser trochanter. From its attachment to the front of the neck of the femur many of the fibres are reflected upwards along the neck as longitudinal bands, termed *retinacula.* The capsular ligament is much thicker at the upper and fore part of the joint, where the greatest amount of resistance is required ; behind and below, it is thin and only loosely connected to the bone. It consists of two sets of fibres, circular and longitudinal. The circular

FIG. 546.—A section through the hip-joint. The synovial membrane is shown in *blue.*



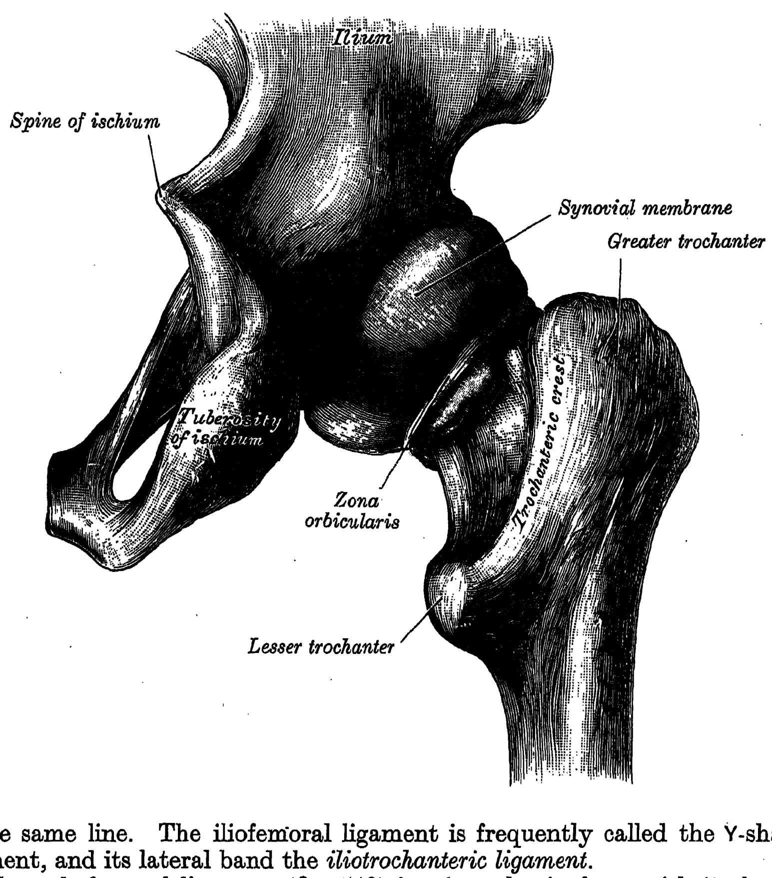
fibres (*zona orbicularis*) are the deeper (fig. 546) and form a collar or ring round the neck of the femur (fig. 547). Although partially blended with the pubo- and ischio-femoral ligaments, these fibres have no direct attachment to bone. The longitudinal fibres are greatest in number at the upper and front part of the capsule, where they are reinforced by the *iliofemoral ligament.* The articular capsule is also strengthened by the *pubofemoral* and the *ischiofemoral ligaments.* The external surface of the capsule is rough, covered by numerous muscles, and separated in front from the psoas major and iliacus by a bursa.

The **synovial membrane** is very extensive. Commencing at the margin of the cartilaginous surface of the head of the femur, it covers the portion of the neck which is contained within the joint ; from the neck it is reflected on the internal surface of the capsular ligament, covers both surfaces of the acetabular labrum, ensheathes the ligament of the head of the femur, and covers the mass of fat contained in the acetabular fossa. It is absent, however, from the deep surface of that part of the iliofemoral ligament which is compressed against the head

of the femur in the erect attitude. The joint-cavity communicates sometimes with the bursa of the psoas major tendon through a circular aperture which is situated between the pubofemoral ligament and the vertical band of the iliofemoral ligament.

The **iliofemoral ligament** (fig. 548), triangular in shape and of great strength, lies in front of the joint and is intimately connected with the capsule. Its apex is attached to the lower part of the anterior inferior iliac spine, its base to the trochanteric line of the femur. The medial and lateral parts of the ligament are strong bands, while the central part is relatively thin and weak; the medial band is vertical in direction and is fixed to the lower part of the trochanteric line; the lateral band is oblique and is attached to the tubercle at the upper part

FIG. 547.—The synovial cavity of the right hip-joint (distended). Posterior aspect. (From a specimen prepared by J. C. B. Grant.)



of the same line. The iliofemoral ligament is frequently called the Y-shaped ligament, and its lateral band the *iliotrochanteric ligament.*

The **pubofemoral ligament** (fig. 548) is triangular in form with its base at the hip-bone, where it is attached to the iliopubic (iliopectineal) eminence, the superior ramus of the os pubis, the obturator crest and obturator membrane; below, it blends with the capsule and with the deep surface of the medial band of the iliofemoral ligament.

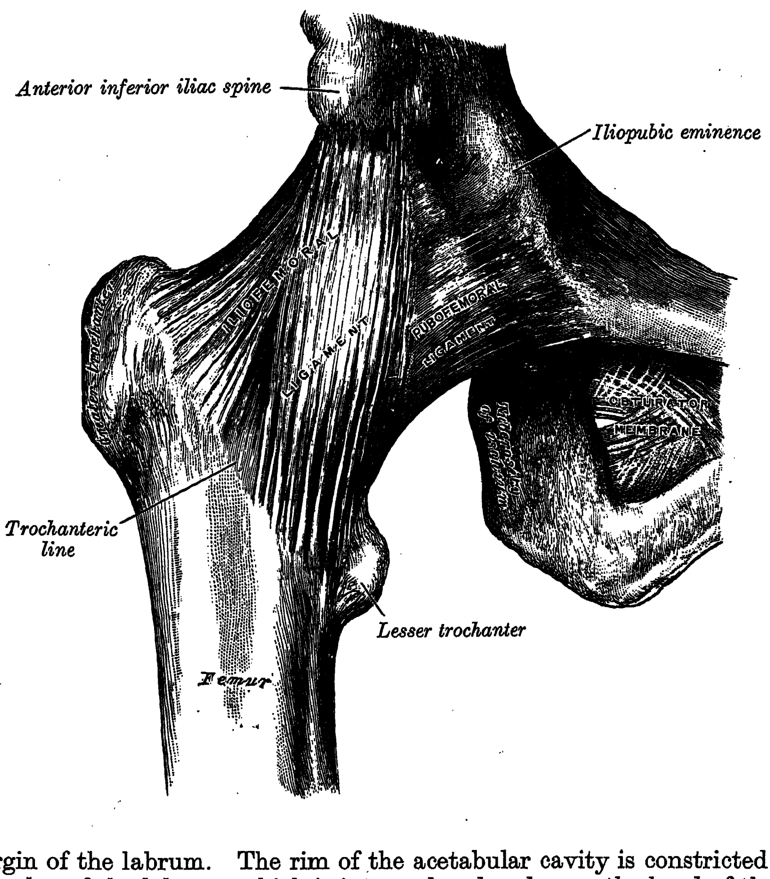
The **ischiofemoral ligament** (fig. 549) has a somewhat spiral disposition on the back of the joint. From its attachment to the ischium below and behind the acetabulum, it is directed upwards and laterally over the back of the neck of the femur. Some of its fibres are continuous with those of the zona orbicularis, others are fixed to the base of the greater trochanter.

The **ligament of the head of the femur (ligamentum teres femoris)** (fig. 550) is a triangular, somewhat flattened band implanted by its apex on the antero-superior part of the pit on the head of the femur; its base is attached by two bands, one into each side of the acetabular notch, and between these bony attachments it blends with the transverse ligament. It is ensheathed by

synovial membrane, and varies greatly in strength in different subjects; occasionally only its synovial sheath exists, and in rare cases even this is absent. The ligament is made tense when the thigh is semiflexed and then adducted; it is relaxed when the limb is abducted.

The **acetabular labrum** (**glenoidal labrum**) (fig. 542) is a fibrocartilaginous rim attached to the margin of the acetabulum, the cavity of which it deepens. It bridges the acetabular notch as the *transverse ligament of the acetabulum*, and thus forms a complete circle. It is triangular on cross-section; the base is attached to the edge of the acetabulum, and the apex corresponds with the free

FIG. 548.—The right hip-joint. Anterior aspect.



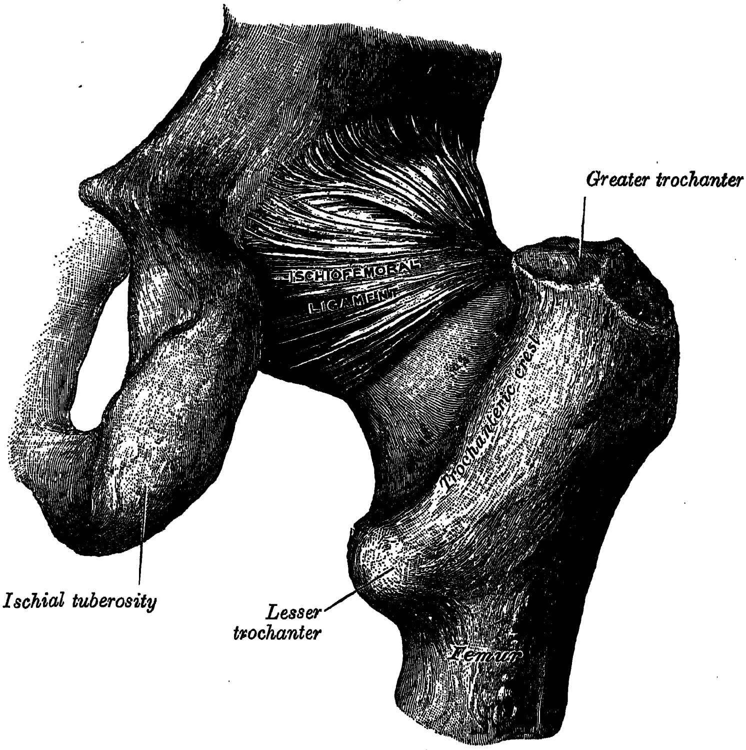
margin of the labrum. The rim of the acetabular cavity is constricted by the free edge of the labrum, which is inturned and embraces the head of the femur closely so as to assist in holding it in its socket.

The **transverse ligament of the acetabulum** (fig. 542) is in reality a portion of the acetabular labrum, though differing from it in having no cartilage-cells among its fibres. It consists of strong, flattened fibres, which cross the acetabular notch, and convert it into a foramen through which vessels and nerves enter the joint.

Relations of the hip-joint.—The capsule is surrounded by muscles on all sides (fig. 551). *Anteriorly*, the lateral fibres of the pectineus intervene between the most medial part of the capsule and the femoral vein. Lateral to the pectineus the tendon of the psoas major, with the iliacus on its lateral side, runs downwards across the front of the capsule, partly separated from it by a bursa. In this situation the femoral artery is lying on the psoas tendon and the femoral nerve lies deeply in the groove between the tendon and the iliacus. More laterally the straight head of the rectus femoris crosses the joint and, under its lateral border, the deep layer of the iliotibial tract blends with the capsular ligament.

Superiorly, the reflected head of the rectus femoris is in contact with the medial part of the capsule ; the gluteus minimus covers the lateral part and is closely adherent to it. *Inferiorly*, the lateral fibres of the pectineus lie on the capsule as they incline backwards and, more posteriorly, the obturator externus crosses obliquely to gain the posterior aspect of the joint. *Posteriorly*, the lower part of the capsule is covered with the tendon of the obturator externus, which separates it from the quadratus femoris and is accompanied by the ascending branch of the medial circumflex femoral artery. Above that, the tendon of the obturator internus with the two gemelli is in intimate relation with the joint

Fig. 549.—The right hip-joint. Posterior aspect.



and intervenes between it and the sciatic nerve. The nerve to the quadratus femoris lies deep to the obturator internus tendon and descends on the most medial part of the capsule. The uppermost part of the posterior surface of the capsular ligament is crossed by the piriformis.

The *arteries* supplying the joint are derived from the obturator, medial circumflex femoral, and superior and inferior gluteal arteries.

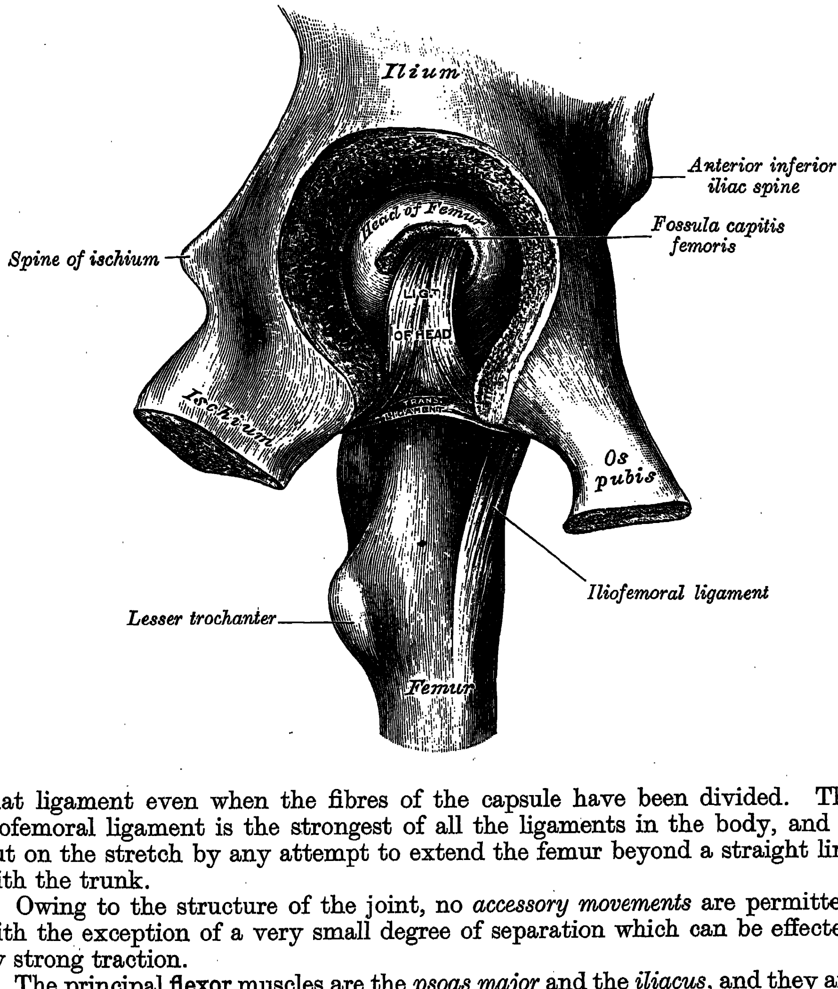
The *nerves* are articular branches from the sacral plexus, the sciatic, obturator, and accessory obturator nerves, a branch from the nerve to the quadratus femoris, and a filament from the branch of the femoral nerve supplying the rectus femoris.

Movements.—The *active movements* of the hip-joint are flexion, extension, adduction, abduction, circumduction, and rotation.

The length of the neck of the femur and its inclination to the body of the bone have the effect of converting the angular movements of flexion, extension, adduction, and abduction partially into rotatory movements in the joint. Thus when the thigh is flexed or extended, the head of the femur rotates within the acetabulum around a transverse axis. Rotation of the thigh takes place around a vertical axis which passes through the centre of the head of the femur and the intercondylar notch. The movements of abduction and adduction occur around an anteroposterior axis which passes through the centre of the head of the femur.

The hip-joint presents a very striking contrast to the shoulder-joint as regards the mechanical arrangements for its security and for the limitation of its movements. In the shoulder, as has been seen, the head of the humerus is not adapted in size to the glenoid cavity, and its ordinary movements are restrained but little by the capsule. In the hip-joint, on the contrary, the head of the femur is closely fitted to the acetabulum for an area extending over nearly half a sphere, and at the margin of the bony cup it is embraced still more closely by the acetabular labrum, so that the head of the femur is held in its place by

FIG. 550.—The left hip-joint, opened by the removal of the floor of the acetabulum from within the pelvis.



that ligament even when the fibres of the capsule have been divided. The iliofemoral ligament is the strongest of all the ligaments in the body, and is put on the stretch by any attempt to extend the femur beyond a straight line with the trunk.

Owing to the structure of the joint, no *accessory movements* are permitted with the exception of a very small degree of separation which can be effected by strong traction.

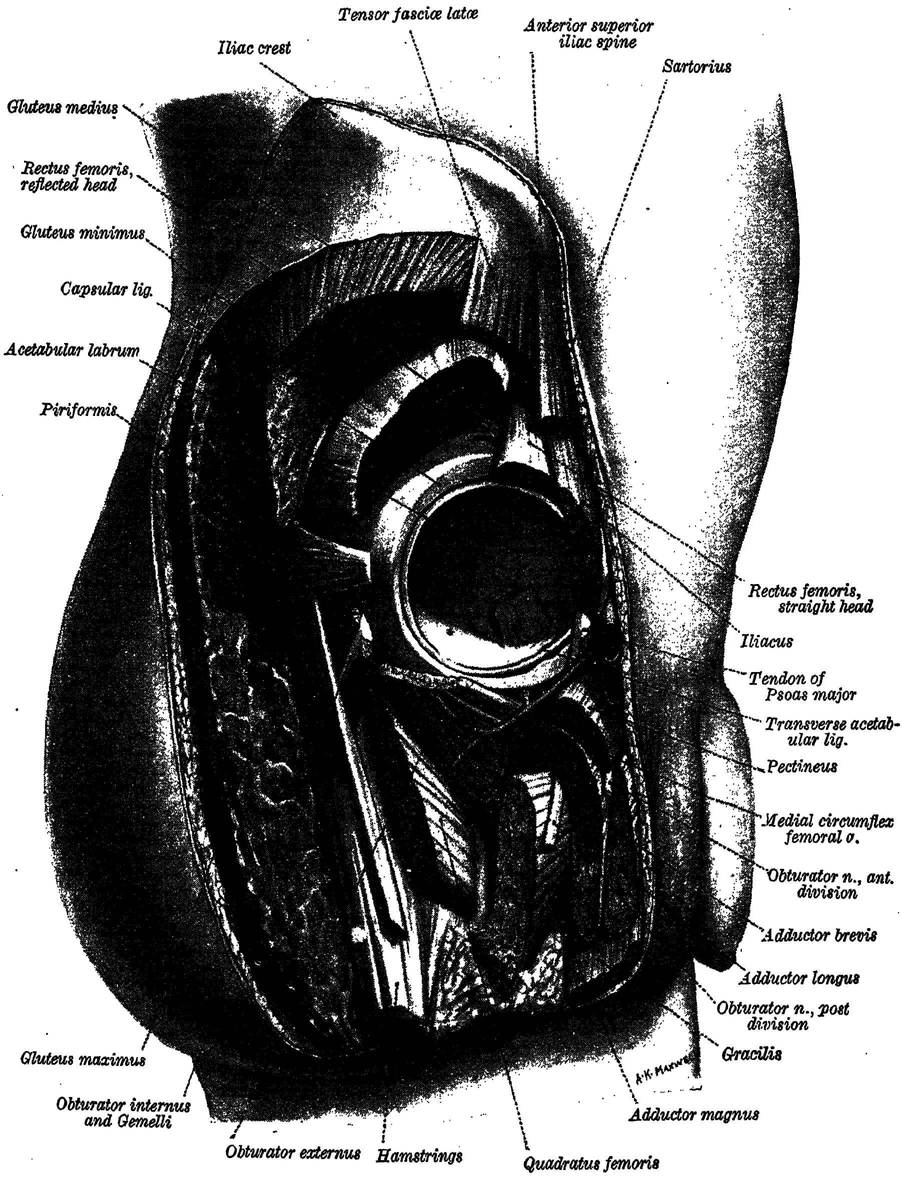
The principal **flexor** muscles are the *psoas major* and the *iliacus*, and they are assisted by the pectineus, rectus femoris and sartorius. The adductors may participate in the movement when it is performed against strong resistance. When the knee is flexed, flexion of the hip-joint is arrested by contact of the front of the thigh with the anterior abdominal wall. When extension of the knee is maintained, flexion of the hip-joint is limited at an earlier stage by the tension of the hamstring muscles.

The principal **extensor** muscle is the *gluteus maximus*, which is the true antagonist of the psoas major and iliacus. The hamstring muscles share in the production of the movement, when strong resistance is encountered. In the erect posture a vertical line passing through the centre of gravity of the trunk falls behind the line joining the centres of the femoral heads, and therefore the pelvis tends to fall backwards, but it is kept in position by the balanced tone

of the flexor and extensor muscles. The iliofemoral ligaments prevent hyperextension.

The principal **abductor** muscles are the *gluteus medius* and the *gluteus minimus*, and they are assisted by the tensor fasciæ latæ and the sartorius. Abduction is a free movement and it is limited by the tension of the adductor

Fig. 551.—The structures surrounding the right hip-joint.



muscles, the pubofemoral ligament and the medial band of the iliofemoral ligament. The principal **adductor** muscles are the *adductores longus, brevis et magnus,* assisted by the pectineus and the gracilis. Adduction is limited by contact with the opposite limb, but a wider range of movement can be obtained when the thigh is flexed. Adduction of the flexed thigh is limited by the tension of the abductor muscles, the lateral band of the iliofemoral ligament and the ligament of the head of the femur.

Medial rotation is a relatively weak movement and no great force is required to prevent it. The principal muscles concerned are the *tensor fasciæ latæ* and the *anterior fibres of the glutei minimus et medius*. The movement is limited by the tension of the lateral rotator muscles, the ischiofemoral ligament and the posterior part of the capsular ligament. **Lateral rotation** can be effected with considerable power. The principal muscles concerned are the *obturatores*, the *gemelli* and the *quadratus femoris*, assisted by the *piriformis*, the gluteus maximus, the sartorius and the adductors. The movement is limited by the tension of the medial rotator muscles and by the lateral band of the iliofemoral ligament.

Applied Anatomy.—In dislocation of the hip, " the head of the thigh-bone may rest at any point around its socket " (Bryant); but whatever position it assumes ultimately, the primary displacement is generally downwards and medially, the capsule giving way at its weakest—that is, its lower and medial—part. The situation subsequently assumed by the head of the bone is determined by the degree of flexion or extension, and of lateral or medial rotation of the thigh at the moment of dislocation, influenced, no doubt, by the iliofemoral ligament, which is not easily ruptured.

The iliofemoral ligament is rarely torn in dislocations of the hip, and this fact is taken advantage of by the surgeon in reducing these dislocations by manipulation. It is made to act as the fulcrum to a lever, of which the long arm is the body of the femur, and the short arm the neck of the bone.

Congenital dislocation is met with more commonly in the hip-joint than in any other articulation. The displacement usually takes place on to the dorsum ilii, the upper part of the rim of the acetabulum being deficient.

IV. THE KNEE-JOINT

The knee-joint is a ginglymus or hinge-joint. It consists of three articulations: two condyloid joints between the condyles of the femur and the semilunar cartilages (menisci) and condyles of the tibia; and a third between the patella and the femur, partly plane, but not completely so, since the articular surfaces are not mutually adapted to each other, so that the movement is not a simple gliding one. This view of the construction of the knee-joint receives confirmation from a study of the articulation in some of the lower mammals, where, corresponding to these three subdivisions, three synovial cavities are found, either distinct from one another or connected by small communications.

The joint is partly subdivided by two semilunar fibrocartilages, which are placed between the femur and the tibia.

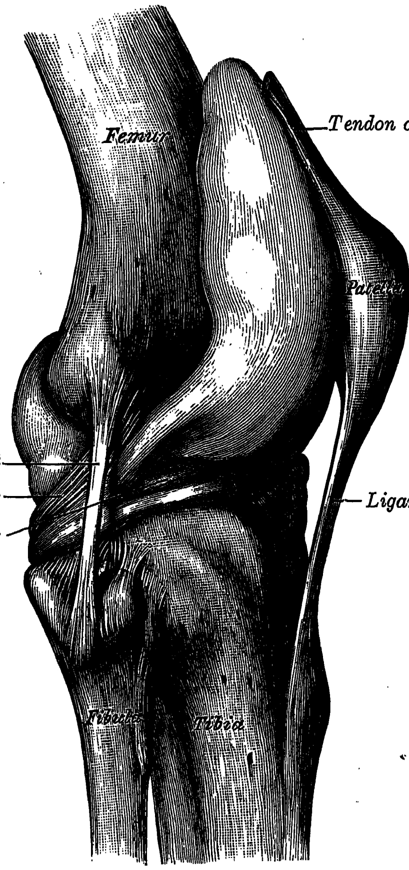
The *articular surfaces* (pp. 390, 395 and 396) are not perfectly congruent. The femoral condyles are convex from side to side and from before backwards, the curvature being accentuated posteriorly (fig. 458). Each tibial articular surface, on the other hand, though gently hollowed out centrally, is flattened around its periphery where it is covered with the corresponding semilunar cartilage. The opposing femorotibial surfaces are adapted to one another more closely by the semilunar cartilages, which are shaped so as to render the inferior articular surface concave both from side to side and from before backwards. The articular surface of the lateral femoral condyle is marked in front by a faint groove (fig. 457) which rests on the peripheral border of the lateral semilunar cartilage in full extension of the joint. A similar groove marks the articular surface of the medial condyle, but it does not reach the lateral border of the condyle, where a narrow strip is marked off which comes into contact with the medial part of the patellar articular surface in full flexion of the knee.

The articular surface of the patella is adapted in a general way to the patellar surface of the femur. The vertical ridge which divides it into a larger, lateral part and a smaller, medial part fits into the corresponding groove on the femur, but the lateral and medial parts are only imperfectly congruent with the corresponding parts of the femur. The articular surface of the patella is divided still further by two faint, horizontal ridges which, with the vertical ridge map out three pairs of facets.* On the medial side a second vertical ridge

* In many patellæ only one horizontal ridge can be made out. It is better marked on the lateral area, and the upper and lateral facet differs from the others in being more deeply hollowed out.

cuts off a narrow, elongated, semilunar strip from the medial border of the surface. This strip comes into contact with the lateral part of the anterior end of the medial femoral condyle in full flexion, and in that position of the joint the uppermost lateral facet on the patella is in contact with the anterior part of the lateral condyle. As the knee is extended the middle facets of

Fig. 552.—The synovial cavity of the right knee-joint (distended). Lateral aspect. (From a specimen prepared by J. C. B. Grant.)



the patella come into contact with the lower half of the femoral patellar surface, and in full extension only the lowest patellar facets are in contact with the femur.

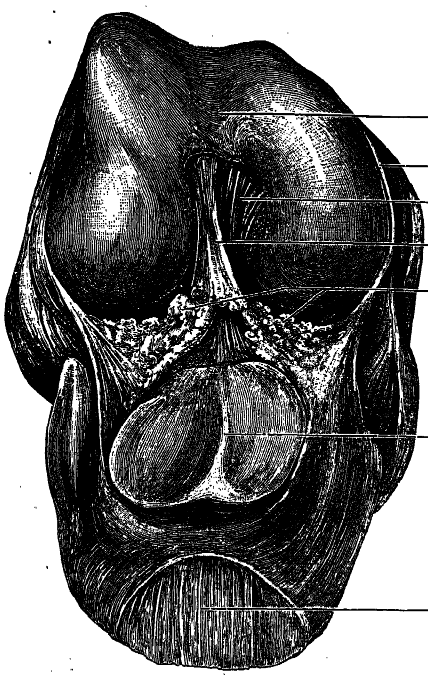
The ligaments of the joints are :

The capsular.	Anterior and posterior cruciate.
Ligamentum patellæ.	Transverse.
Oblique posterior and arcuate.	Coronary.
Medial and lateral.	

The **capsular ligament** is a very complicated structure, for in part it is deficient and in part it is replaced by strong expansions from the tendons of the muscles which surround the joint. Posteriorly, it consists of vertically running fibres which are attached above to the margins of the femoral condyles and the posterior margin of the intercondylar notch, and below to the posterior margins of the tibial condyles and the posterior border of the intercondylar area. This part of the capsule is blended above on each side with the origin of the corresponding head of the gastrocnemius and centrally it is strengthened by the oblique posterior ligament with which its fibres interlace. On the medial side the fibres are attached to the medial surfaces of the femoral and tibial condyles

beyond the articular margins. In this situation the capsular ligament blends with the deep fibres of the medial (tibial collateral) ligament. On the lateral side the fibres are attached to the femur above the origin of the popliteus and they descend to the lateral condyle of the tibia covering the muscle. The lateral (fibular collateral) ligament stands clear of the capsule and is separated from it by a little fat and the inferior lateral genicular vessels and nerve. Anteriorly, the capsule is entirely awanting above the patella and over the patellar area. Elsewhere it blends indistinguishably with expansions from the vastus medialis and vastus lateralis. These expansions are attached to the margins of the patella and ligamentum patellæ and extend backwards on each side as far as the corresponding collateral ligament and downwards to the condyles of the tibia. They form the *medial* and *lateral patellar retinacula,*

FIG. 553.—The right knee-joint. Opened from the front.

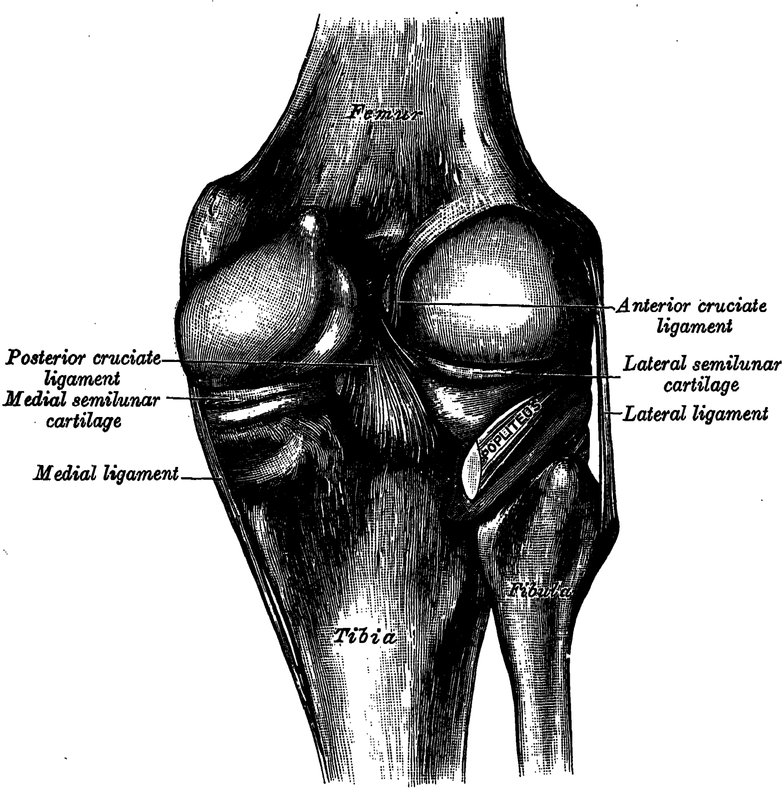


and the latter is further strengthened by the iliotibial tract, which partially covers and blends with the expansion from the vastus lateralis. Above the patella the deficiency of the capsule allows the suprapatellar bursa (p. 498) to communicate freely with the cavity of the joint. Posteriorly, the attachment of the capsule to the posterior surface of the lateral tibial condyle is interrupted, and in this situation the popliteus emerges from within the capsule (fig. 556). The oblique posterior ligament, which is augmented by fibres derived from the tendon of the semimembranosus, strengthens the posterior aspect of the capsule. Laterally, a prolongation from the iliotibial tract fills the interval between the oblique posterior and the lateral (fibular collateral) ligaments, and partly covers the latter. Medially, expansions from the sartorius and semimembranosus pass upwards to the medial (tibial collateral) ligament and strengthen the capsule.

The **synovial membrane** of the knee-joint is the most extensive in the body. Commencing at the upper border of the patella, it forms a large pouch under cover of the quadriceps femoris on the lower part of the front of the femur (figs. 552, 560), and usually communicates with a bursa interposed between the tendon and the front of the bone. The pouch between the quadriceps and front of the femur is upheld, during the movements of the knee, by a small muscle,

named the articularis genu, which is inserted into it. On either side of the patella, the synovial membrane extends beneath the aponeuroses of the vasti, and more especially beneath that of the vastus medialis. Below the patella it is separated from the ligamentum patellæ by a considerable quantity of fat, known as the *infrapatellar pad*. Opposite the medial and lateral borders of the lower part of the articular surface of the patella, the synovial membrane covering the infrapatellar pad is projected into the interior of the joint in the form of two fringe-like folds termed the *alar folds*; behind, these folds converge and are continued as a single band, named the *infrapatellar fold*, to the front of the intercondylar notch of the femur (fig. 553). By its position, attachments and

FIG. 554.—The synovial cavity of the right knee-joint (distended). Posterior aspect of the specimen represented in fig. 552.



structure the infrapatellar fold may be identified as a vestige of the inferior boundary of the originally separate femoropatellar joint (p. 491).

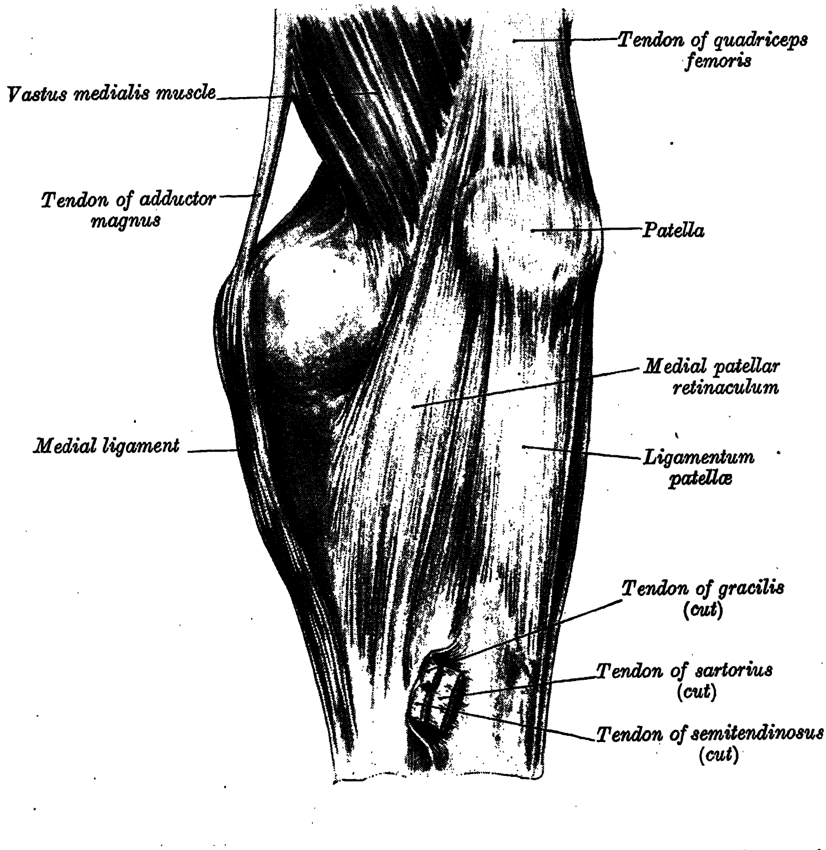
At the sides of the joint the synovial membrane passes downwards from the femur, lining the capsular ligament as far as its attachment to the semilunar cartilages. In the fœtus it may then be traced over the upper surfaces of these to their free borders, and thence along their under surfaces to the tibia, but, in the adult, owing to the pressure to which they have been subjected, the fibro-cartilages are devoid of a synovial investment. At the back part of the lateral semilunar cartilage the synovial membrane forms a cul-de-sac between the groove on the surface of the cartilage and the tendon of the popliteus.

The **ligamentum patellæ** (fig. 555) is the central portion of the common tendon of the quadriceps femoris, which is continued from the patella to the tubercle of the tibia. It is a strong, flat, ligamentous band, about 8 cm. in length, attached, above, to the apex and adjoining margins and to the rough depression on the lowest part of the posterior surface of the patella; and below, to the upper part of the tubercle of the tibia; its superficial fibres are con-

tinuous over the front of the patella with those of the tendon of the quadriceps femoris. The medial and lateral portions of the tendon of the quadriceps pass down, one on each side of the patella, to be inserted into the upper extremity of the tibia, one on each side of the tubercle; these portions merge into the capsular ligament, as stated above, forming the medial and lateral patellar retinacula. The posterior surface of the ligamentum patellæ is separated from the synovial membrane by a large infrapatellar pad of fat, and from the tibia by a bursa.

The **oblique posterior ligament** (oblique popliteal ligament) (fig. 556) is a broad, flat, fibrous band, formed of fasciculi separated from one another by apertures for the passage of vessels and nerves. It is attached, above, to the lateral part of the intercondylar line and to the lateral condyle of the femur, and

Fig. 555.—The left knee-joint. Anteromedial aspect.



below, it gradually blends with the capsular ligament, which constitutes its principal connexion. It consists of a strong fasciculus which is derived from the tendon of the semimembranosus close to its insertion into the tibia, and it becomes partially blended with the capsule as it passes upwards and laterally across its posterior part. The oblique posterior ligament forms part of the floor of the popliteal fossa, and the popliteal artery rests upon it.

The **arcuate ligament of the knee** (arcuate popliteal ligament) (fig. 556) is an arched bundle of fibres which varies somewhat in strength and appearance. It is attached to the lateral condyle of the femur and passes downwards to fuse with the capsular ligament. Two bands, an anterior and a posterior, converge from the upper and lower extremities of the arcuate ligament; they unite below to form the *retinaculum* of the ligament, which is fixed to the styloid process of the head of the fibula. The anterior band of this retinaculum is sometimes described as the *short lateral (fibular collateral) ligament* and the

popliteus emerges from under cover of the posterior band (fig. 556). In fig. 556 the oblique upper border of the arcuate ligament shows an upward concavity, but in many cases it is straight and blended with the capsule. Some anatomists describe the ligament as a Λ-shaped band, consisting of femorotibial and femoro-fibular parts, which straddle the emerging tendon of the popliteus muscle.

The **medial** (tibial collateral) **ligament** (figs. 555, 561) is a broad, flat band, situated nearer to the back than to the front of the joint. It is attached, above, to the medial epicondyle of the femur immediately below the adductor tubercle; below, to the medial condyle and medial surface of the shaft of the tibia. The fibres of the posterior part of the ligament are short and incline backwards

Fig. 556.—The right knee-joint. Posterior aspect.

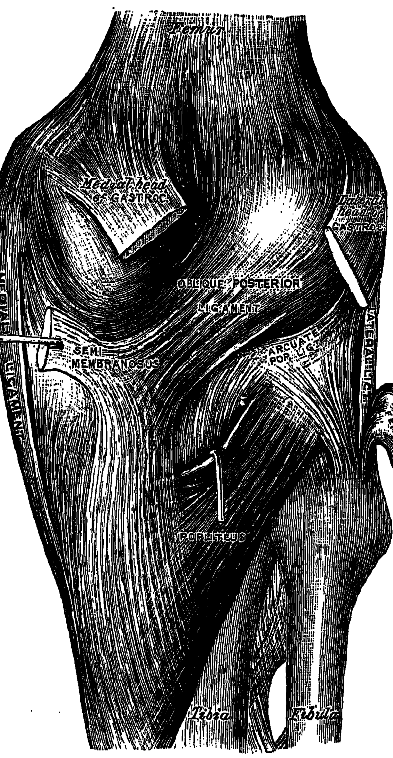
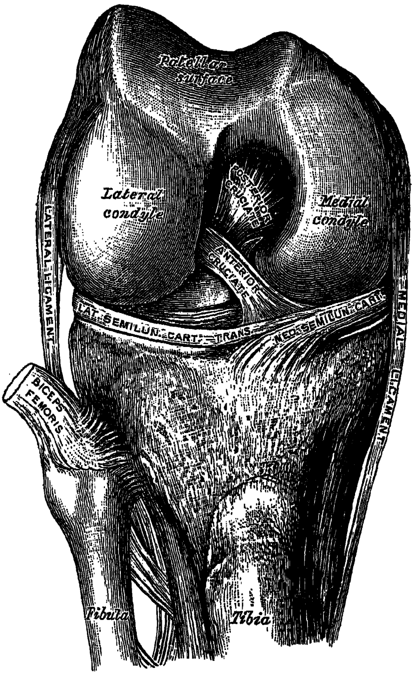


Fig. 557.—The right knee-joint. Dissected from the front.



as they descend; they are inserted into the tibia above the groove for the semimembranosus. The anterior part of the ligament, about 10 cm. long, inclines forwards as it descends; it is inserted into the medial margin and the posterior part of the medial surface of the shaft of the tibia (fig. 468). It is crossed, at its lower part, by the tendons of the sartorius, gracilis, and semitendinosus, a bursa being interposed. Its deep surface covers the inferior medial genicular vessels and nerve, and the anterior portion of the tendon of the semimembranosus with which it is connected by a few fibres; *its upper part is intimately adherent to the periphery of the medial semilunar cartilage.*

The **lateral** (fibular collateral) **ligament** (fig. 557) is a strong, rounded cord, attached, above, to the lateral epicondyle of the femur, immediately above the groove for the tendon of the popliteus; below, to the lateral side of the head of the fibula, in front of the styloid process. The greater part of it is hidden by the tendon of the biceps femoris, but the tendon divides at its insertion into two parts, which are separated by the ligament. Deep to the ligament are the tendon of the popliteus and the inferior lateral genicular vessels and nerve. *The ligament has no attachment to the lateral semilunar cartilage.*

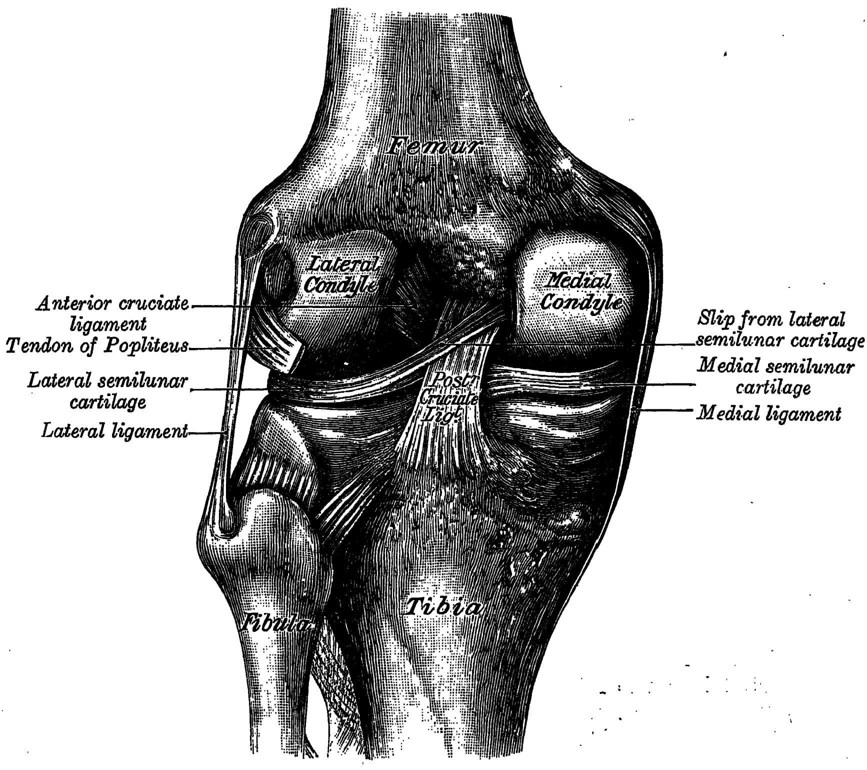
The **cruciate ligaments** are of considerable strength, and are situated in the

middle of the joint, nearer to its posterior than its anterior surface. They are called *cruciate* because they cross each other somewhat like the limbs of the letter X; and have received the names *anterior* and *posterior*, from the position of their attachments to the tibia. Their position within the joint justifies their identification as collateral ligaments of the originally separate medial and lateral femorotibial joints (p. 491).

The **anterior cruciate ligament** (fig. 559) is attached to the medial part of the anterior portion of the intercondylar area of the tibia, being partly blended with the anterior end of the lateral semilunar cartilage; it passes upwards, backwards and laterally, and is attached to the posterior part of the medial surface of the lateral condyle of the femur.

The **posterior cruciate ligament** (fig. 558) is stronger, but shorter and less oblique in its direction, than the anterior. It is attached to the posterior part

FIG. 558.—The left knee-joint. Dissected from behind.



of the intercondylar area of the tibia, and to the posterior extremity of the lateral semilunar cartilage; it passes upwards, forwards and medially, to be attached to the lateral surface of the medial condyle of the femur.

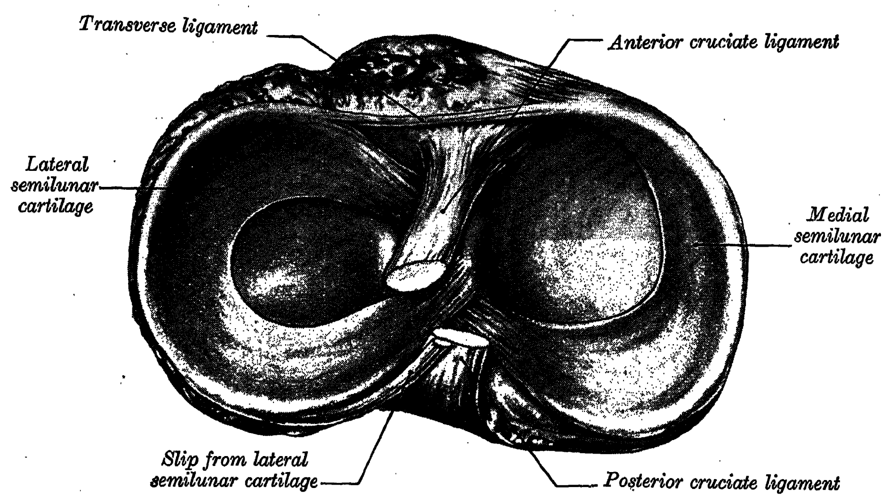
The **semilunar cartilages** (menisci) (fig. 559) are two crescentic lamellæ, which serve to deepen the surfaces of the upper end of the tibia for articulation with the condyles of the femur. The peripheral border of each cartilage is thick and convex; the opposite border is thin, concave, and free. The upper surfaces of the cartilages are smooth and concave, and in contact with the condyles of the femur; their lower surfaces are smooth and flat, and rest upon the tibia. Each covers approximately the peripheral two-thirds of the corresponding articular surface of the tibia.

The **medial semilunar cartilage** is nearly semicircular in form, and is broader behind than in front; its anterior end is attached to the anterior part of the intercondylar area of the tibia, in front of the anterior cruciate ligament, its posterior fibres being continuous with the transverse ligament; its posterior end is fixed to the posterior part of the intercondylar area of the tibia, between

the attachments of the lateral semilunar cartilage and the posterior cruciate ligament. Its peripheral border is attached to the capsular ligament and *is firmly adherent to the deep surface of the medial ligament of the knee-joint.*

The lateral semilunar **cartilage** is nearly circular and covers a larger portion of the articular surface than the medial cartilage. It is of the same breadth throughout its extent, and is grooved posteriorly by the tendon of the popliteus, which separates it from the lateral ligament of the knee-joint. Its anterior end is attached in front of the intercondylar eminence of the tibia, behind and lateral to the anterior cruciate ligament, with which it partly blends; the posterior end is attached behind the intercondylar eminence of the tibia, in front of the posterior end of the medial cartilage. The anterior attachment of the lateral semilunar cartilage is twisted so that its free margin looks backwards and upwards, its anterior end resting on a sloping shelf of bone on the front of the lateral intercondylar tubercle. Close to its posterior attachment it sends off a strong fasciculus (figs. 558, 559), which passes upwards and medially, to be inserted into the medial condyle of the femur, immediately behind the attachment of

FIG. 559.—The upper end of the left tibia, showing the semilunar cartilages and the lower ends of the cruciate ligaments.



the posterior cruciate ligament. Occasionally a small fasciculus passes forwards to be inserted into the lateral part of the anterior cruciate ligament. *The tendon of the popliteus muscle intervenes between the lateral semilunar cartilage and the lateral ligament of the knee-joint.*

The **transverse ligament** (fig. 559) connects the anterior convex margin of the lateral to the anterior end of the medial semilunar cartilage; its thickness varies considerably in different subjects, and it is sometimes absent.

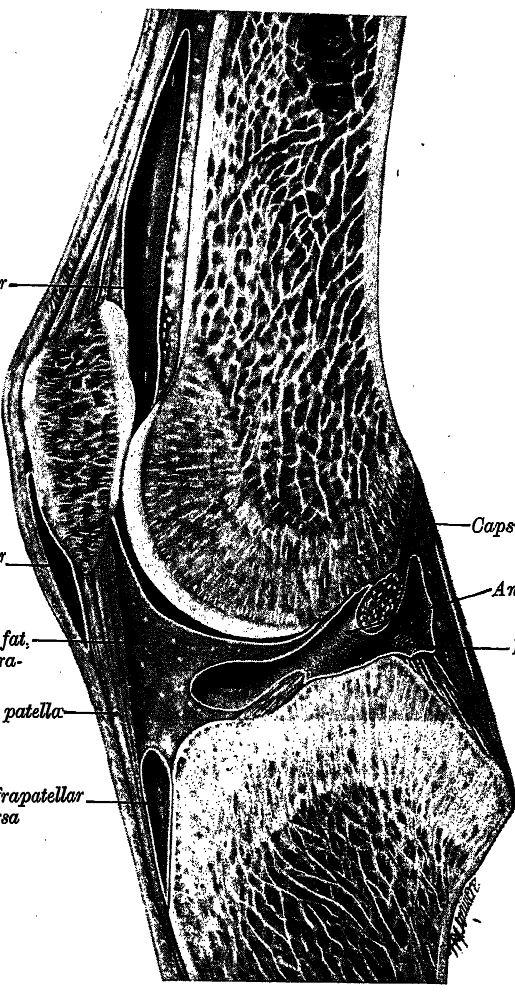
The **coronary ligaments** are merely portions of the capsule, connecting the periphery of each semilunar cartilage with the margin of the head of the tibia.

Bursæ.—The bursæ near the knee-joint are the following:

In front there are four bursæ: a large one (*subcutaneous prepatellar bursa*) is interposed between the lower part of the patella and the skin, a small one (*deep infrapatellar bursa*) between the upper part of the tibia and the ligamentum patellæ, a third (*subcutaneous infrapatellar bursa*) between the lower part of the tubercle of the tibia and the skin, and a fourth, of large size (*suprapatellar bursa*), which usually communicates with the knee-joint, between the anterior surface of the lower part of the femur and the deep surface of the quadriceps femoris (fig. 560). Laterally there are four bursæ: (1) one (which sometimes communicates with the joint) between the lateral head of the gastrocnemius and the capsule; (2) one between the lateral ligament and the tendon of the biceps femoris; (3) one between the same ligament and the tendon of the popliteus (this is sometimes only an expansion from the next bursa); (4) one between the

tendon of the popliteus and the lateral condyle of the femur, usually an extension from the synovial membrane of the joint. Medially, there are five bursæ: (1) one between the medial head of the gastrocnemius and the capsule: this sends a prolongation between the tendon of the medial head of the gastrocnemius and the tendon of the semimembranosus and often communicates with the joint; (2) one (*tibial intertendinous bursa*) superficial to the medial ligament, between it and the tendons of the sartorius, gracilis, and semitendinosus; (3) one deep to the medial ligament, between it and the tendon of the semi-

FIG. 560.—A sagittal section through the right knee-joint. Lateral aspect. The synovial membrane is shown in colour.



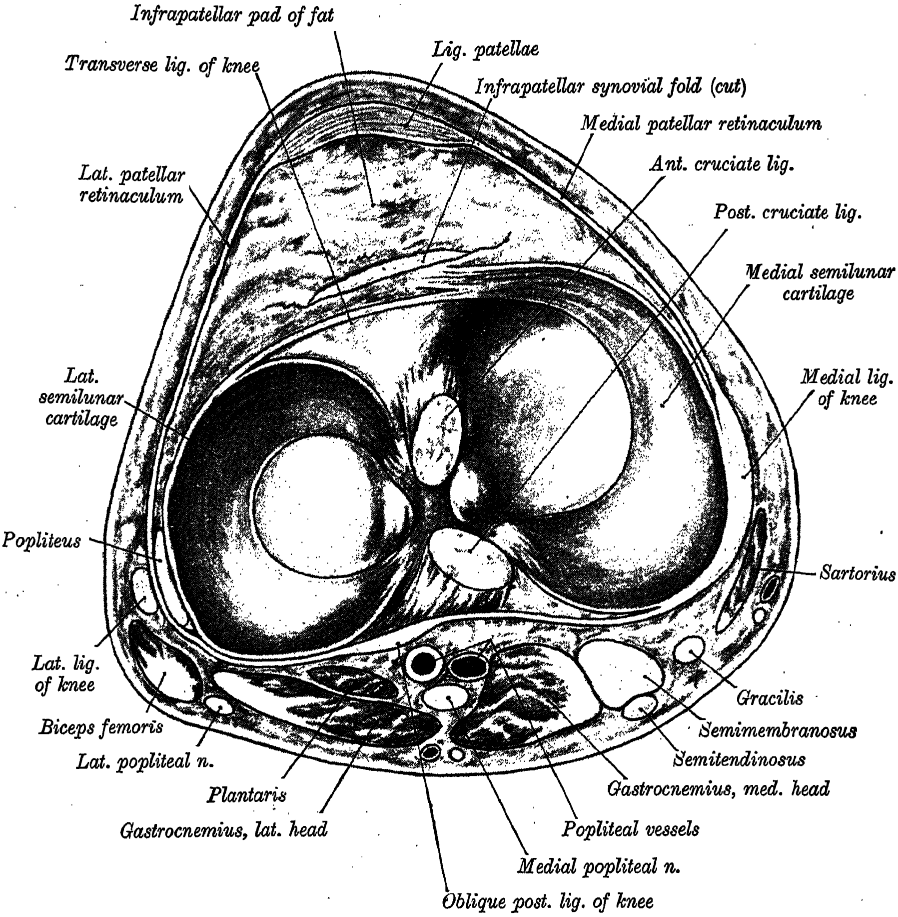
membranosus (this is sometimes only an expansion from the next bursa); (4) one between the tendon of the semimembranosus and the medial condyle of the tibia; (5) occasionally there is a bursa between the tendons of the semimembranosus and semitendinosus.

Structures around the joint.—*Anteriorly*, the quadriceps femoris covers the joint, and tendinous expansions from the vastus medialis and vastus lateralis extend backwards from its margins over the *anteromedial* and *anterolateral* aspects of the capsule, respectively, forming the patellar retinacula. On the *posteromedial* side the sartorius, with the gracilis tendon lying along its posterior border, descends across the joint; on the *posterolateral* side the biceps tendon, with the lateral popliteal nerve on its medial side, is in contact with the capsule, which separates it from the popliteus (fig. 561). The *posterior* relations are the most numerous and the most important. The popliteal artery, with its

associated lymph glands, lies on the posterior ligament; the popliteal vein is posteromedial, or medial, to the artery; and the medial popliteal nerve is posterior to both vessels. The nerve and vessels are overlapped by the adjoining edges of the two heads of the gastrocnemius and, on the lateral side, by the plantaris. On each side of the vessels the corresponding head of the gastrocnemius comes into intimate relation with the capsule, and on the medial side of the medial head the semimembranosus intervenes between the capsule and the semitendinosus.

The *arteries* supplying the joint are the descending genicular (a. genu suprema), the genicular branches of the popliteal, the recurrent branches of

FIG. 561.—A transverse section of the left knee-joint, viewed from above, to show the relations of the joint.



the anterior tibial, and the descending branch from the lateral circumflex femoral branch of the arteria profunda femoris.

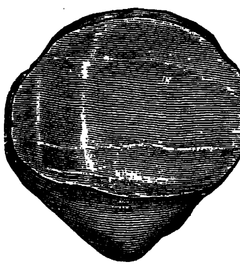
The *nerves* are derived from the obturator, femoral, medial and lateral popliteal (tibial and common peroneal).

Movements.—The active movements which can be carried out at the knee-joint are flexion, extension, medial rotation and lateral rotation. The movements of flexion and extension differ from those of a typical hinge-joint, such as the elbow, in two ways. Firstly, the axis around which the movement occurs is not fixed, but shifts forwards during extension of the leg on the thigh and backwards during flexion. Secondly, extension is associated with a minor degree of lateral rotation of the leg, and flexion with a corresponding degree of medial rotation. In full flexion the posterior parts of the tibial articular surfaces are in contact with the posterior parts of the articular surfaces of the

femoral condyles. During extension the tibia and its semilunar cartilages glide forwards on the femoral condyles and the axis around which the movement takes place gradually shifts forwards. As a result the point of contact between the two bones moves forwards also, carrying the semilunar cartilages with it. As the movement progresses the flatter curve of the femoral condyles makes contact with the tibia, and the curves of the semilunar cartilages are opened out, the net result being that the anterior ends of the cartilages move forwards, while their posterior ends suffer little change in position. In flexion the reverse movement occurs, so that the cartilages adapt their outline to the curve of the parts of the femoral condyles which are making contact with the tibia.

The movement of lateral rotation* of the tibia which is associated with extension of the bone on the femur constitutes a locking mechanism which is of importance when the fully extended knee is subjected to strain. The axis of rotation passes vertically through the lateral condyle medial to its centre, and on this account the medial tibial condyle has a longer traverse than the lateral, and the articular surfaces of both the tibia and the femur reflect this fact. It is usually stated that the lateral rotation referred to occurs at the last stage of extension and has the effect of screwing the joint home and locking it. It must be observed, however, that the rotation is not necessary to ensure stability in the erect posture, for in that position the joint is not fully extended, and it can be extended voluntarily still further until the limit of the movement is reached. This is due to the fact that although the weight of the trunk falls behind the line joining the centres of the femoral heads, it falls in front of the transverse axis of the knee-joint and tends to cause hyperextension of the joint. This is prevented by the tension of the hamstring muscles, so that the quadriceps is partially relaxed in the erect attitude and, as a result, the patella lies loosely on the front of the lower end of the femur.

FIG. 562.—The posterior surface of the right patella, showing diagrammatically the areas of contact with the femur in different positions of the knee-joint.



In addition to the rotatory movements associated with extension and flexion, medial and lateral rotation of the leg can be effected when the joint is partly flexed; these movements are freest when the leg is bent at right angles with the thigh.

At the limit of flexion the ligamentum patellæ and part of the posterior cruciate ligament are stretched, while the oblique posterior and collateral ligaments and, to a slight extent, the anterior cruciate ligament are relaxed. Flexion is checked during life by the contact of the leg with the thigh. When the knee-joint is fully extended the oblique posterior, collateral and anterior cruciate ligaments and the posterior fibres of the posterior cruciate ligament are tense; in the act of extending the knee the ligamentum patellæ is tightened by the quadriceps femoris, but in the erect attitude it is relaxed for reasons already stated. Medial rotation is checked by the anterior cruciate ligament and the tension of the biceps femoris; lateral rotation tends to uncross and relax the cruciate ligaments, but is checked by the collateral ligaments and the tension of the medial rotators. The main function of the cruciate ligaments is to act as a direct bond between the tibia and femur and to prevent the former bone from being carried too far backwards or forwards. They also assist the collateral ligaments in resisting any bending of the joint to either side. The semilunar cartilages ensure that perfect contact is maintained between the articular surfaces in all positions of the joint. They move with the femur on the tibia in gliding and rotatory movements, but with the tibia on the femur in flexion and extension. The patella is a great defence to the front of the knee-joint; it also affords leverage to the quadriceps femoris.

Accessory movements.—A wider range of rotation can be obtained by passive movements than can be performed actively when the joint is semiflexed, and in

* The actual mechanism whereby this rotation is effected is very difficult to explain, and none of the theories hitherto advanced is really satisfactory.

this position the tibia can be made to glide backwards and forwards on the femur. When the knee is slightly flexed a limited amount of adduction and abduction can be obtained, and it may be noted that these movements can be performed actively, provided that the foot is on the ground. A slight amount of separation of the femur and tibia can be obtained on strong traction.

Muscles producing the movements :

In **flexion**, the *biceps femoris, semitendinosus* and *semimembranosus* are the principal muscles concerned, but they receive assistance from the gracilis, sartorius and popliteus. When the foot is on the ground, the gastrocnemius and the plantaris are capable of participating in the movement.

In **extension**, the *quadriceps femoris* is the chief muscle concerned, but it receives some assistance from the tensor fasciæ latæ.

In **medial rotation of the flexed leg**, the *popliteus, semimembranosus* and *semitendinosus* are the chief agents, but they may be assisted by the sartorius and the gracilis.

In **lateral rotation of the flexed leg**, the biceps femoris is the only muscle concerned.

Applied Anatomy.—From a consideration of the construction of the knee-joint, it would at first sight appear to be one of the least secure joints in the body. It is formed between the two longest bones, and therefore the amount of leverage which can be brought to bear upon it is considerable; the articular surfaces are but ill-adapted to each other, and the range of motion which it enjoys is great. All these circumstances tend to render the articulation insecure; nevertheless, on account of the powerful ligaments which bind the bones together and the strength of the muscles concerned, the joint is one of the strongest in the body, and dislocation from traumatism is a rare occurrence.

One or other of the semilunar cartilages may be torn or detached, tearing being the commoner accident; when a cartilage is torn it is the thin, central portion which is separated. The torn part projects into the interior, and leads to locking of the joint in the semiflexed position. The accident is produced by a twist of the leg when the knee is slightly flexed, and is accompanied by a sudden pain, and often by fixation of the knee in the flexed position. The torn part of the cartilage may be displaced either towards the tibial intercondylar eminence, so that it becomes lodged in the intercondylar notch, or to one side, so that it projects beyond the margin of the two articular surfaces. The medial semilunar cartilage is much more commonly affected than the lateral because it is more securely attached to neighbouring structures (p. 497) and is therefore less able to adapt itself to sudden changes of position. Further, during the slight rotation of the joint it moves through a greater interval than the lateral cartilage.

The cruciate ligaments are sometimes ruptured, but great violence is necessary to produce this injury. When the anterior is torn the tibia can be pushed forwards; when the posterior is torn the tibia can be pulled backwards.

Acute synovitis, the result of traumatism, is of frequent occurrence in the knee-joint. When the cavity is distended with fluid, the swelling shows itself above and at the sides of the patella, reaching about 2·5 cm., occasionally 5 cm. or more, above the patellar surface of the femur, and extending a little higher under the vastus medialis than under the vastus lateralis. The lower level of the synovial membrane is just below the upper end of the tibia.

The bursæ about the knee-joint are sometimes the seat of enlargement. The bursa between the front of the patella and the skin is frequently affected in those who are in the habit of kneeling, and the condition is known as 'housemaid's knee.' The bursa beneath the semimembranosus tendon also occasionally becomes enlarged, and forms a fluctuating swelling at the back of the knee. During extension the swelling is firm and tense; but during flexion it becomes soft, and, as the bursa often communicates with the synovial cavity of the joint, the fluid it contains can be made to disappear by pressure when the knee is flexed.

III. THE TIBIOFIBULAR JOINTS

The tibia and the fibula are connected at their extremities by (1) the superior and (2) the inferior tibiofibular joints. (3) In addition, the shafts of the bones are connected by the crural interosseous membrane.

1. The Superior Tibiofibular Joint

This articulation (fig. 558) is a plane joint between the lateral condyle of the tibia and the head of the fibula. The *articular surfaces* of the bones present flat, oval facets covered with cartilage, and the bones are connected by a capsular ligament and by anterior and posterior ligaments.

The **capsular ligament** is attached to the margins of the articular facets on the tibia and fibula ; it is much thicker in front than behind. Not infrequently the synovial membrane of the joint is continuous with that of the knee-joint through the popliteus bursa.

The **anterior ligament** consists of two or three flat bands, which pass obliquely upwards from the front of the head of the fibula to the front of the lateral condyle of the tibia.

The **posterior ligament** is a thick band, which passes obliquely upwards from the back of the head of the fibula to the back of the lateral condyle of the tibia. It is covered by the tendon of the popliteus.

2. The Crural Interosseous Membrane

The **crural interosseous membrane** connects the interosseous borders of the tibia and fibula, and separates the muscles on the front from those on the back of the leg. The anterior tibial artery passes to the front of the leg through a large oval opening in the uppermost part of the membrane, and the perforating branch of the peroneal artery pierces its lower part. It consists of oblique fibres, which for the most part run downwards and laterally; a few, however, pass downwards and medially, including a bundle which forms the upper border of the opening for the anterior tibial artery. The membrane is continuous below with the interosseous ligament of the inferior tibiofibular joint. It is in relation, in front, with the tibialis anterior, extensor digitorum longus, extensor hallucis longus, peroneus tertius, and the anterior tibial vessels and anterior tibial (deep peroneal) nerve; behind, with the tibialis posterior and flexor hallucis longus.

3. The Inferior Tibiofibular Joint (Tibiofibular Syndesmosis)

This syndesmosis is formed by the rough, convex surface on the medial side of the lower end of the fibula, and a rough, concave surface (the fibular notch) on the lateral side of the tibia. Below, to the extent of about 4 mm., these surfaces are smooth, and covered with cartilage continuous with that of the ankle-joint. The ligaments are : anterior, posterior, inferior transverse and interosseous.

The **anterior inferior tibiofibular ligament** (fig. 567) is a flattened band, which extends obliquely downwards and laterally between the adjacent margins of the tibia and fibula, on the front of the syndesmosis.

The **posterior inferior tibiofibular ligament** (fig. 564), smaller than the preceding, is disposed in a similar manner on the posterior surface of the syndesmosis. Its lower and deep portion forms the **inferior transverse ligament**—a strong, thick band of yellowish fibres which passes transversely from the upper part of the malleolar fossa of the fibula to the posterior border of the articular surface of the tibia, almost as far as the medial malleolus. The inferior transverse ligament projects below the margins of the bones, and forms part of the articulating surface for the talus.

The **interosseous ligament** is continuous, above, with the crural interosseous membrane and consists of numerous, short, strong bands which pass between the adjacent rough surfaces of the tibia and fibula, and constitute the chief bond of union between the lower ends of the bones.

IV. THE ANKLE-JOINT

The ankle-joint is a ginglymus, or hinge-joint. The lower end of the tibia and its malleolus, the malleolus of the fibula, and the inferior transverse tibiofibular ligament enter into its formation, and together form a mortise for the reception of the body of the talus. The *articular surfaces* are covered with hyaline cartilage. The trochlear surface of the talus, which is convex from before backwards and gently concave from side to side, is *wider in front than behind*, and the inferior articular surface of the tibia is reciprocally shaped. The articular surface for the medial malleolus is restricted to the upper part of the medial surface of the talus. It is flat and comma-shaped, being deeper in

front than behind. The lateral surface of the talus, which is triangular in outline, is concave from above downwards and adapts itself to the articular surface of the lateral malleolus, which is convex from above downwards.

Fig. 563.—The synovial cavity of the left ankle-joint (distended). Lateral aspect. (From a specimen prepared by J. C. B. Grant.)

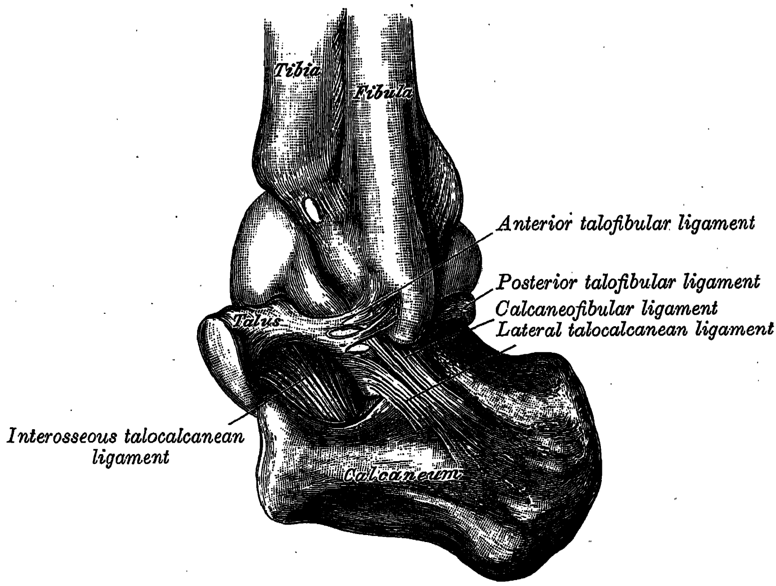
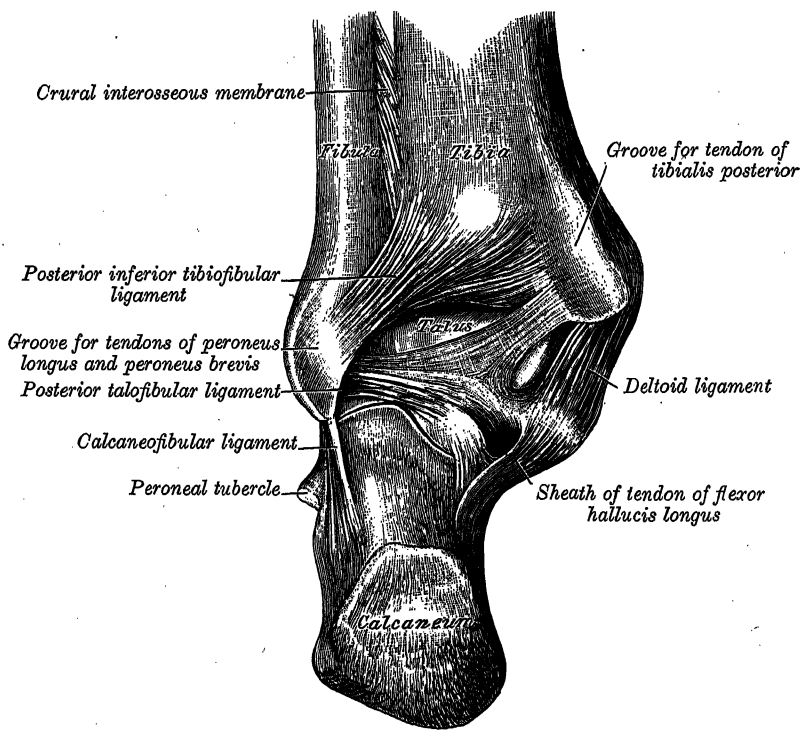


Fig. 564.—The left ankle-joint. Posterior aspect.



The bones are connected by the following ligaments :

Capsular.	Lateral.
Anterior and posterior.	Anterior and posterior talofibular.
Deltoid.	Calcaneofibular.

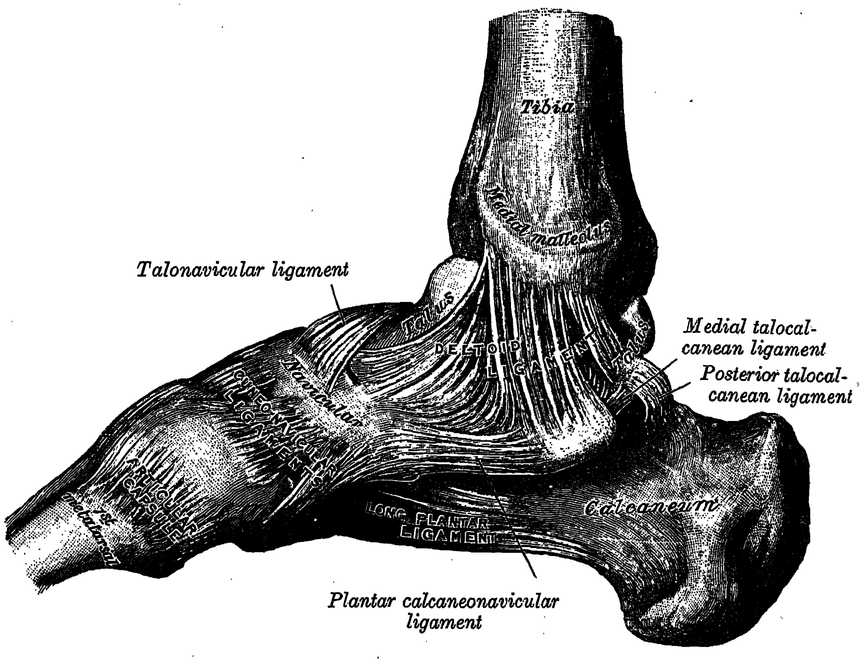
The **capsular ligament** (fig. 565) surrounds the joint, and is attached, above, to the borders of the articular surfaces of the tibia and malleoli. Below, it is attached to the dorsum of the neck of the talus a little in front of the trochlear surface, and elsewhere it is attached close to the margins of the articular surfaces.

The **anterior ligament** is a broad, thin, membranous layer attached, above, to the anterior margin of the lower end of the tibia, and below to the talus, a little in front of its superior articular surface.

The **posterior ligament** is very thin and consists principally of transverse fibres. It is attached, above, to the posterior margin of the articular surface of the tibia, blending with the inferior transverse ligament, and below, to the talus behind its superior articular facet. Laterally, it is somewhat thickened and reaches as far as the malleolar fossa of the fibula.

A synovial membrane lines the capsular ligament, and the joint-cavity ascends for a short distance between the tibia and fibula (fig. 568).

Fig. 565.—The ligaments of the right ankle and tarsus. Medial aspect.



The **deltoid ligament** (figs. 565, 568) is a strong, triangular band, attached, above, to the apex and anterior and posterior borders of the medial malleolus. It consists of two sets of fibres, superficial and deep. Of the superficial fibres the anterior (*tibionavicular*) pass forwards to be attached to the tuberosity of the navicular bone, and immediately behind this they blend with the medial margin of the plantar calcaneonavicular ligament; the middle fibres (*calcaneotibial*) descend almost perpendicularly and are fixed to the whole length of the sustentaculum tali of the calcaneum; the posterior fibres (*posterior talotibial*) pass backwards and laterally to be attached to the medial side of the talus, and to its medial tubercle. The deep fibres (*anterior talotibial*) are fixed above, to the tip of the medial malleolus, and, below, to the non-articular part of the medial surface of the talus. The deltoid ligament is crossed by the tendons of the tibialis posterior and flexor digitorum longus.

The **lateral ligament** consists of three separate bands, termed the anterior talofibular, the posterior talofibular and the calcaneofibular.

The **anterior talofibular ligament** (fig. 567) passes from the anterior margin of the fibular malleolus, forwards and medially, to the talus, where it is attached in front of the lateral articular facet and to the lateral aspect of the neck.

The **posterior talofibular ligament** (fig. 564), strong and deeply seated, runs

FIG. 566.—Transverse section through the lower part of the ankle-joint.

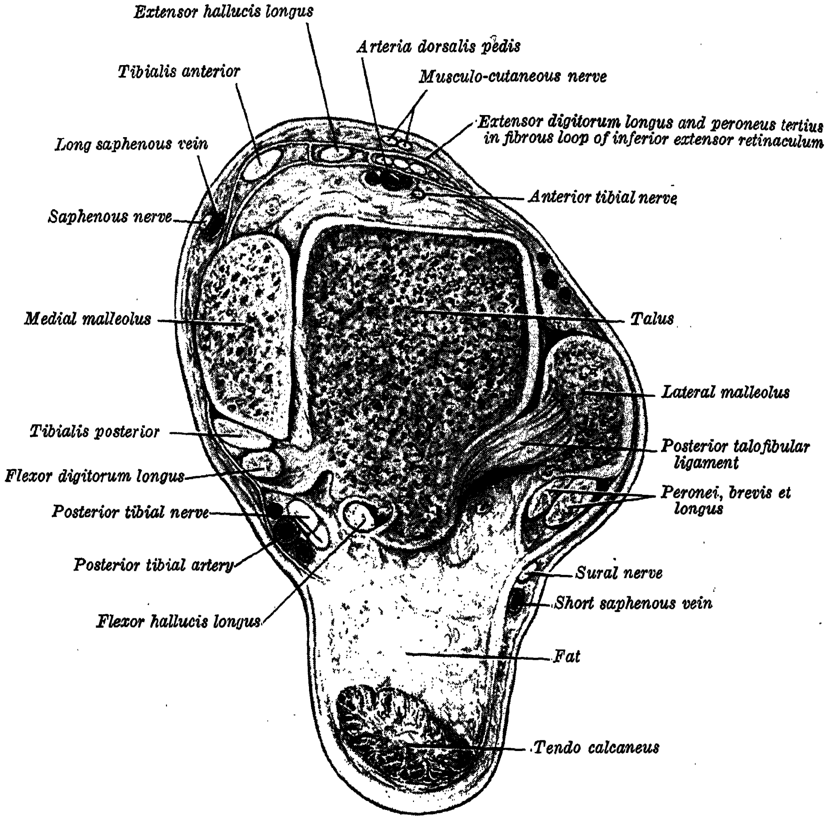
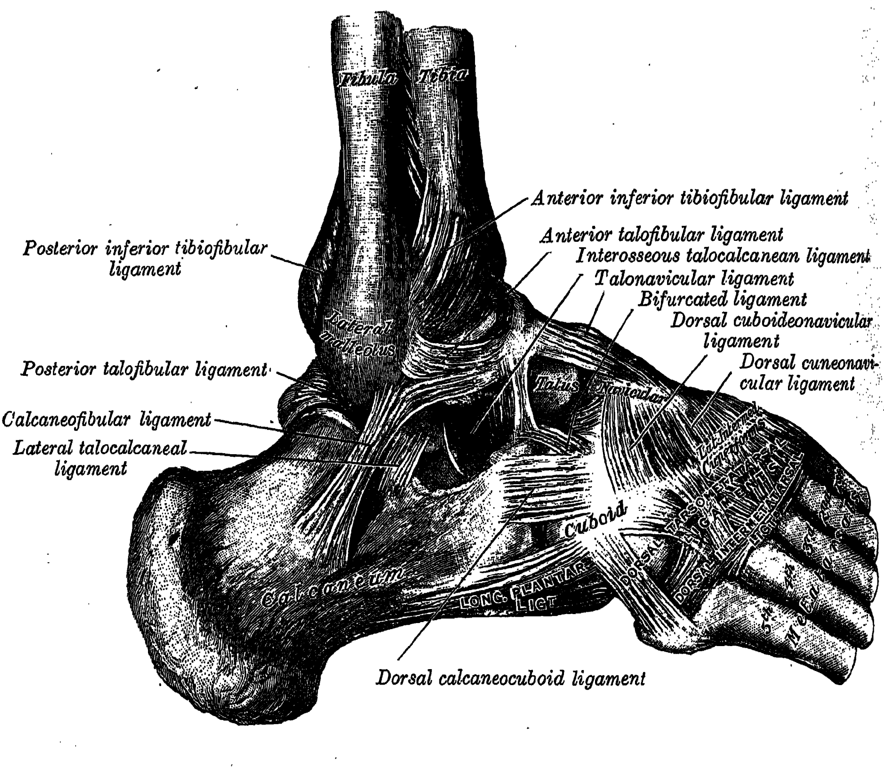


FIG. 567.—The ligaments of the right ankle and tarsus. Lateral aspect.



almost horizontally from the lower part of the malleolar fossa to the posterior tubercle of the talus.

The **calcaneofibular ligament** (fig. 567) is a long rounded cord, running from the depression in front of the apex of the fibular malleolus downwards and slightly backwards to a tubercle on the lateral surface of the calcaneum. It is crossed by the tendons of the peroneus longus and brevis.

Relations.—The tendons, vessels, and nerves in relation with the joint are: in front, from the medial side, the tibialis anterior, extensor hallucis longus, anterior tibial vessels, anterior tibial (deep peroneal) nerve, extensor digitorum longus, and peroneus tertius; behind, from the medial side, the tibialis posterior, flexor digitorum longus, posterior tibial vessels, posterior tibial nerve (tibial nerve), flexor hallucis longus; and, in the groove behind the fibular malleolus, the tendons of the peroneus longus and brevis (fig. 566).

The *arteries* supplying the joint are derived from the malleolar branches of the anterior tibial and from the peroneal.

The *nerves* are derived from the anterior and posterior tibial (deep peroneal and tibial).

Movements.—When the body is in the erect position the foot is at right angles to the leg. The *active movements* of the ankle-joint are those of dorsiflexion and plantar-flexion; in dorsiflexion the angle between the front of the leg and the dorsum of the foot is diminished; in plantar-flexion the angle is increased, the heel being raised and the toes pointed downwards. The malleoli embrace the talus in the position of rest, and no appreciable degree of side-to-side movement can occur without stretching of the ligaments of the inferior tibiofibular joint, and slight bending of the fibula. The superior articular surface of the talus is broader in front than behind. In dorsiflexion, therefore, greater space is required between the two malleoli. This is obtained by a slight separation of the lower ends of the tibia and fibula and is consequent on slight movement at the inferior tibiofibular joint; this movement is facilitated by a minor degree of gliding at the superior tibiofibular joint. The deltoid ligament is exceedingly strong—so much so, that it usually resists a force which fractures the process of bone to which it is attached. Its middle portion, together with the calcaneofibular ligament, binds the bones of the leg firmly to the foot, and resists displacement in every direction. The posterior talofibular ligament assists the calcaneofibular in resisting the displacement of the foot backwards, and deepens the cavity for the reception of the talus. The anterior talofibular ligament is a security against the displacement of the foot forwards. Plantar-flexion of the foot is limited by the tension of the opposing muscles, by the anterior fibres of the deltoid and by the anterior talofibular ligament. Dorsiflexion of the foot is limited by the tension of the tendo calcaneus, by the posterior fibres of the deltoid and by the calcaneofibular ligament.

Accessory movements.—Slight amounts of side to side gliding movement, rotation, abduction and adduction are permitted, when the foot is in plantar flexion.

Muscles producing the movements :

In **dorsiflexion** the *tibialis anterior* is the most important factor, but it receives appreciable assistance from the extensor digitorum longus, the extensor hallucis longus and the peroneus tertius.

In **plantar-flexion,** the *gastrocnemius* and the *soleus* are the chief agents, assisted to a lesser degree by the peroneus longus and brevis, the plantaris, the tibialis posterior, the flexor hallucis longus and the flexor digitorum longus.

Applied Anatomy.—Owing to the protection afforded to the talus by the tibiofibular mortise, the ankle-joint is a very stable articulation and dislocation is rare unless one of the malleoli is fractured. So-called sprains of the ankle-joint are almost always abduction sprains of the subtalar joints, although some of the fibres of the deltoid ligament also are torn. True sprains of the ankle-joint are usually caused by forced plantar flexion and result in tearing of the capsular ligament on the front of the joint and bruising by impaction of the structures at the back of the joint.

When disease or injury of the ankle-joint is likely to lead to ankylosis, the joint is kept dorsiflexed to rather less than a right angle.

V. THE INTERTARSAL JOINTS

1. The Talocalcanean Joint

There are two articulations between the calcaneum and talus, an anterior and a posterior; the anterior forms part of the talocalcaneonavicular joint, and is described with it (p. 509). The posterior or talocalcanean joint is formed between the convex, posterior calcanean facet on the inferior surface of the talus, and the concave, posterior facet on the superior surface of the calcaneum. It is a plane joint, and the two bones are connected by a capsular ligament and by anterior, posterior, lateral, medial and interosseous talocalcanean ligaments.

The **capsular ligament** envelops the joint, and consists for the most part of

Fig. 568.—A coronal section through the left ankle and talocalcaneal joints.

short fibres; it is split into slips, and between these there is only a weak fibrous investment. It is lined with synovial membrane, and the joint-cavity does not communicate with any of the other tarsal joints.

The **anterior talocalcanean ligament** (fig. 570) extends from the inferior and lateral surfaces of the neck of the talus to the superior surface of the calcaneum. It is identical with the posterior part of the interosseous talocalcanean ligament.

The **posterior talocalcanean ligament** (fig. 565) connects the posterior tubercle of the talus with the upper surface of the calcaneum close to the posterior facet; it is a short band, and its fibres radiate from their narrow attachment on the talus.

The **lateral talocalcanean ligament** (fig. 567) is a short, flattened fasciculus, which passes downwards and backwards from the lateral tubercle of the talus to be attached to the lateral surface of the calcaneum, above and in front of the calcaneofibular ligament.

The **medial talocalcanean ligament** connects the medial tubercle on the

posterior surface of the talus with the back of the sustentaculum tali. Its fibres blend with those of the deltoid ligament.

The **interosseous talocalcanean ligament** (figs. 568, 570) forms the chief bond of union between the bones and is attached, above, to the sulcus tali ; below, to the sulcus calcanei. It comprises the posterior ligament of the talocalcaneo-navicular joint and the anterior ligament of the talocalcanean joint. Medially, these two ligaments are fused, but laterally they are separated by a band of fibres derived from the fibrous loop which encloses the tendons of the peroneus tertius and the extensor digitorum longus in front of the ankle-joint (p. 650). The lateral part of the anterior portion of the talocalcanean interosseous ligament is especially strengthened and extends between the inferolateral aspect of the neck of the talus and the upper surface of the calcaneum (fig. 570). It is rendered taut when the foot is inverted and prevents the occurrence of too great a degree of this movement.

Movements.—The movements permitted between the talus and calcaneum are closely associated with the movements at the talocalcaneonavicular joint and will be described with them.

2. The Talocalcaneonavicular Joint

This articulation is a restricted form of ball-and-socket joint : the rounded head of the talus being received into the concavity formed by the posterior surface of the navicular, the anterior upper articular surface of the calcaneum, and the upper surface of the plantar calcaneonavicular ligament. The bones forming the joint are connected by a capsular ligament, and by the talonavicular, the plantar calcaneonavicular and the lateral calcaneonavicular ligaments.

The **capsular ligament** is imperfectly developed except posteriorly, where it is considerably thickened and forms the anterior part of the interosseous ligament, which fills the sinus tarsi formed by the opposing grooves on the calcaneum and talus, as mentioned above.

The **talonavicular ligament** (fig. 565) is a broad, thin band, connecting the neck of the talus to the dorsal surface of the navicular bone ; it is covered with the extensor tendons. The plantar calcaneonavicular ligament (p. 511) is the plantar, and the lateral calcaneonavicular (*vide infra*) the lateral ligament for this joint.

Movements.—A considerable range of gliding and rotatory movement is permitted at both the talocalcanean and the talocalcaneonavicular joints. The calcaneum and the navicular, carrying the foot with them, can be moved medially on the talus in a combination of gliding movement and rotation.* This movement results in the elevation of the medial border and a corresponding depression of the lateral border of the foot, so that the plantar aspect of the foot faces medially. This is the position of *inversion*, which is in reality a combination of adduction and partial 'supination'. The range of the movement is appreciably increased in plantar flexion of the foot, for in this position the narrow part of the trochlear surface of the talus occupies the tibiofibular mortise and a slight amount of lateral movement of the talus in the mortise gives an increased range of adduction to the front part of the foot. The opposite movement, which is much more limited in range, is termed *eversion*. The chief factor in the limitation of inversion is the tension of the peronei and the strong lateral part of the interosseous talocalcanean ligament (p. 499). The other tarsal interosseous ligaments and the calcaneofibular ligament are less important factors. Eversion is arrested by the tension of the tibialis anterior and tibialis posterior and the deltoid ligament.

Muscles producing the movements:

Inversion.—Tibialis anterior and posterior.
Eversion.—Peroneus longus and brevis.

3. The Calcaneocuboid Joint

The articular surfaces of the calcaneocuboid joint are somewhat saddle-shaped. The ligaments of the joint are : the capsular, the dorsal calcaneo-

* For a full analysis of these movements, consult a paper by Philip Wiles : "Flat-Feet," *The Lancet*, 1934.

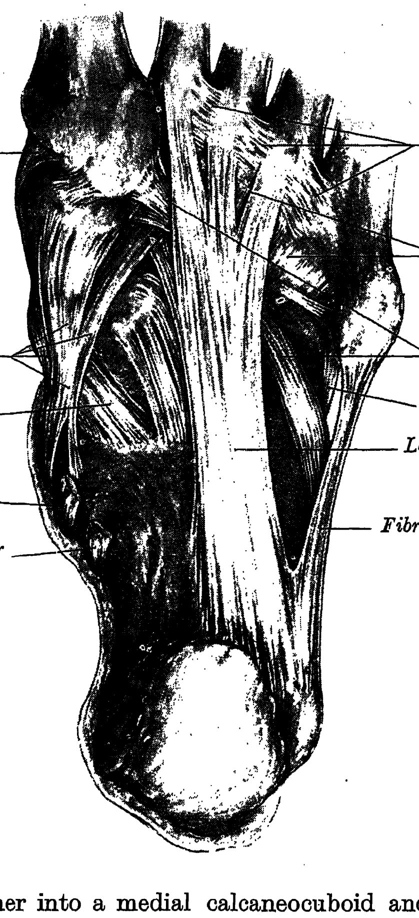
cuboid, the calcaneocuboid portion of the bifurcated ligament, the long plantar and the short plantar (plantar calcaneocuboid).

The **capsular ligament** contains certain bands which form the other ligaments of the joint. Its synovial membrane is distinct from that of the other tarsal articulations (fig. 571).

The **dorsal calcaneocuboid ligament** (fig. 567) is a thin but broad fasciculus, which passes between the contiguous surfaces of the calcaneum and the cuboid bone, on the dorsal surface of the joint.

The **bifurcated ligament** (figs. 567, 570) is a strong band attached behind to the anterior part of the upper surface of the calcaneum and dividing in front

FIG. 569.—The ligaments of the plantar surface of the left foot.



in a Y-shaped manner into a medial calcaneocuboid and a lateral calcaneonavicular ligament. The *medial calcaneocuboid ligament* is fixed to the dorsal part of the medial side of the cuboid bone and forms one of the principal bonds between the first and second rows of the tarsal bones. The *lateral calcaneonavicular ligament* is attached to the dorsilateral aspect of the navicular bone.

The **long plantar ligament** (fig. 569), which is the longest of the tarsal ligaments, is attached posteriorly to the plantar surface of the calcaneum in front of the medial and lateral tubercles, and anteriorly to the ridge and tuberosity on the plantar surface of the cuboid bone, the more superficial fibres being continued forwards to the bases of the second, third, and fourth metatarsal bones. This ligament converts the groove on the plantar surface of the cuboid bone into a tunnel for the tendon of the peroneus longus. It possesses great strength and is an important factor in resisting flattening of the lateral longitudinal arch of the foot (p. 517).

The **short plantar (plantar calcaneocuboid) ligament** (fig. 569) lies nearer to the bones than the preceding ligament, from which it is separated by a little

areolar tissue. It is a short but wide band of great strength, and stretches from the anterior tubercle of the calcaneum and the depression in front of it, to the adjoining part of the plantar surface of the cuboid bone. Like the preceding ligament, it resists flattening of the lateral longitudinal arch of the foot.

Movements.—The movements permitted between the calcaneum and the cuboid bone are limited to slight gliding and rotation of the bones upon each other, and occur during the movements of inversion and eversion.

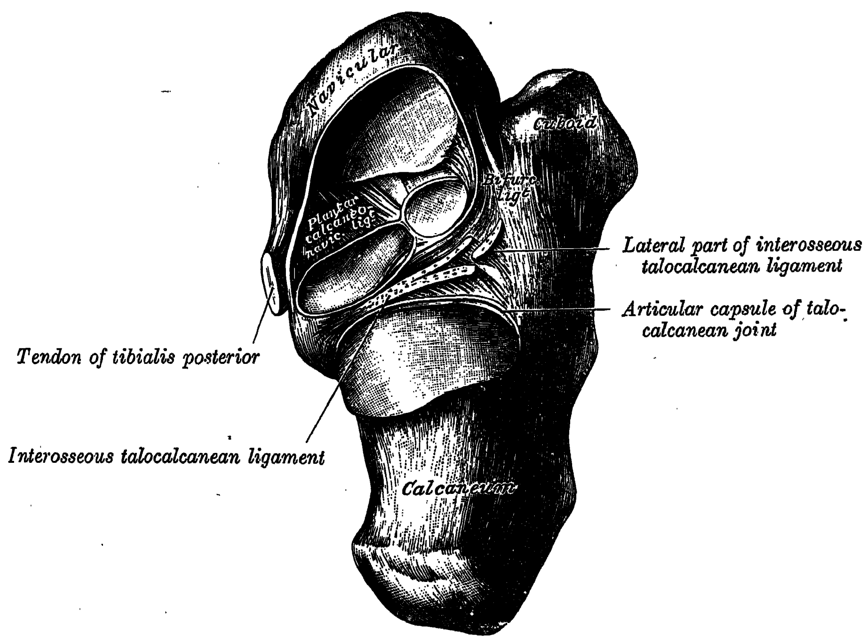
The calcaneocuboid and talonavicular articulations together form what is known as the *transverse tarsal joint*.

4. The Ligaments connecting the Calcaneum and Navicular

Though the calcaneum and the navicular bone do not articulate directly, they are connected by two ligaments: the lateral calcaneonavicular and the plantar calcaneonavicular.

The **lateral calcaneonavicular ligament** has been described above; it forms the medial band of the bifurcated ligament.

Fig. 570.—The right talocalcanean and talocalcaneonavicular joints exposed by removal of the talus.



The **plantar calcaneonavicular** or '**spring**' **ligament** (fig. 569) is a broad, thick band connecting the anterior margin of the sustentaculum tali of the calcaneum to the plantar surface of the navicular bone. This ligament unites the calcaneum with the navicular bone, and lies below the head of the talus, forming part of the articular cavity in which the head is received; it resists flattening of the medial longitudinal arch of the foot (p. 516). The *dorsal surface* of the ligament presents a fibrocartilaginous facet upon which a portion of the head of the talus rests (fig. 570). Its *plantar surface* is supported by the tendon of the tibialis posterior, medially; and by the tendons of the flexor hallucis longus and the flexor digitorum longus, laterally; its *medial border* is blended with the anterior fibres of the superficial part of the deltoid ligament of the ankle-joint.

5. The Cuneonavicular Joint

The navicular bone articulates in front with the three cuneiform bones. The joint is of the plane variety and its *capsular ligament* is continuous with the capsular ligaments of the intercuneiform and the cuneocuboid joints. Its synovial cavity is continuous with the synovial cavities of these joints and with the synovial cavities of the second and third cuneometatarsal joints and of the intermetatarsal joints between the bases of the second and third, and third and fourth metatarsal bones.

Dorsal and plantar ligaments connect the navicular bone to each of the cuneiform bones.

The **dorsal ligaments** are three small fasciculi, one attached to each of the cuneiform bones. The fasciculus connecting the navicular bone with the medial cuneiform bone is continuous round the medial side of the joint with the plantar ligament which unites these two bones.

The **plantar ligaments** have a similar arrangement to the dorsal, and are strengthened by slips from the tendon of the tibialis posterior.

6. The Cubonavicular Joint

The cubonavicular joint is usually a syndesmosis, and the two bones are connected by dorsal, plantar and interosseous ligaments.

The **dorsal ligament** extends obliquely forwards and laterally, while the **plantar** passes nearly transversely from the cuboid bone to the navicular bone.

The **interosseous ligament** consists of strong transverse fibres, and connects the rough non-articular portions of the adjacent surfaces of the two bones.

Not infrequently the syndesmosis is replaced by a synovial joint. In that event the joint is of the plane variety and its capsular ligament and synovial cavity are continuous with those of the cuneonavicular joint.

7. The Intercuneiform and Cuneocuboid Joints

The intercuneiform joints and the joint between the lateral cuneiform bone and the cuboid are all synovial in character and of the plane variety. Their capsular ligaments and synovial cavities are continuous with those of the cuneonavicular joint.

The bones are connected together by dorsal, plantar, and interosseous ligaments.

The **dorsal** and **plantar ligaments** each consist of three transverse bands: one connects the medial and intermediate cuneiform bones, another the intermediate and lateral cuneiform bones, and another the lateral cuneiform and cuboid bones. The plantar ligaments are strengthened by slips from the tendon of the tibialis posterior.

The **interosseous ligaments** connect the rough non-articular portions of the adjacent surfaces of the bones and possess considerable strength; they resist depression of the transverse arch of the foot (p. 517).

Movements.—The movements permitted at the cuneonavicular, cubonavicular, intercuneiform and cuneocuboid joints are limited to a slight amount of gliding on each other of the bones concerned, and cannot be performed voluntarily when the foot is raised from the ground. They occur when load is taken by the anterior part of the foot, *e.g.* in starting to run or jump, etc., and greatly increase the suppleness of the foot.

VI. THE TARSOMETATARSAL JOINTS

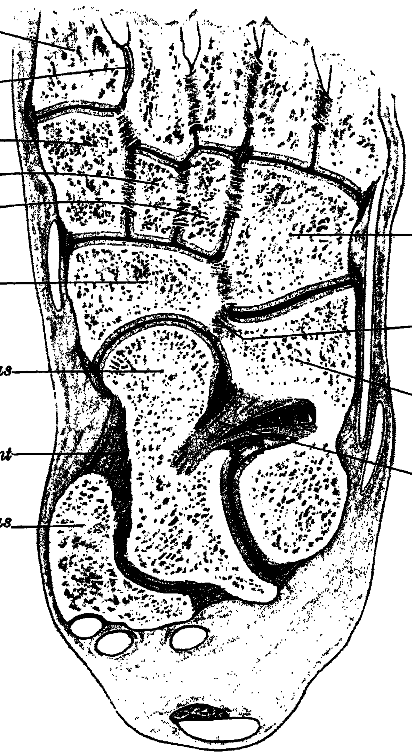
These are synovial joints of the plane variety. The first metatarsal bone articulates with the medial cuneiform bone; the second is dovetailed in between the medial and lateral cuneiform bones, articulating by its base with the intermediate cuneiform bone; the third articulates with the lateral cuneiform bone; the fourth, with the cuboid and lateral cuneiform bones; and the fifth with

the cuboid bone. The first joint possesses an independent capsular ligament and synovial cavity. The capsular ligaments and synovial cavities of the second and third joints are continuous with those of the intercuneiform and cuneonavicular joints, but are shut off from those of the fourth and fifth joints by an interosseous ligament which passes between the lateral cuneiform bone and the base of the fourth metatarsal. The bones are connected by dorsal, plantar, and interosseous ligaments.

The **dorsal ligaments** are strong, flat bands. The first metatarsal is joined to the medial cuneiform bone by a capsular ligament; the second metatarsal receives three bands, one from each cuneiform bone; the third, one from the lateral cuneiform bone; the fourth, one from the lateral cuneiform bone, and another from the cuboid bone; and the fifth, one from the cuboid bone.

The **plantar ligaments** consist of longitudinal and oblique bands, disposed

Fig. 571.—An oblique section through the right foot, showing the synovial cavities of the intertarsal and tarsometatarsal joints. Viewed from above.



N.B.—The section passed below the joint between the medial cuneiform bone and the base of the second metatarsal; no synovial joint was present between the navicular and cuboid bones.

with less regularity than the dorsal ligaments. Those for the first and second metatarsal bones are the strongest; the second and third metatarsal bones are joined by oblique bands to the medial cuneiform bone; the fourth and fifth metatarsal bones are connected by a few fibres to the cuboid bone.

The **interosseous ligaments** are three in number. The first is the strongest and passes from the lateral surface of the medial cuneiform bone to the adjacent angle of the second metatarsal bone (fig. 571). The second connects the lateral cuneiform bone with the adjacent angle of the second metatarsal bone. The third connects the lateral angle of the lateral cuneiform bone with the adjacent side of the base of the third metatarsal bone.

Movements.—The movements permitted between the tarsal and metatarsal bones are limited to gliding of the bones upon each other. This movement is very limited in range except in the case of the joint between the medial cuneiform bone and the first metatarsal, where an appreciable amount both of up

and down movement and of rotation of the metatarsal bone can be obtained passively when the muscles concerned are relaxed. These movements are carried out actively in standing and walking and form part of the mechanism by which the foot is kept plantigrade whether it is inverted or everted.

In order that the inverted foot may remain plantigrade on a flat surface, the elevation of its medial border, which is a necessary accompaniment of inversion, is corrected by medial (or downward) rotation and depression of the first metatarsal and medial cuneiform bones, brought about by the action of the peroneus longus muscle (p. 649). Conversely, in the case of eversion, the elevation of the lateral border of the foot is corrected by lateral (or upward) rotation and elevation of the first metatarsal and medial cuneiform bones, brought about passively by pressure on the ground. As a result of these movements the transverse arch of the foot (p. 517) is accentuated in inversion and flattened in eversion.

VII. THE INTERMETATARSAL JOINTS

The base of the first metatarsal bone is not connected with that of the second by any ligaments; in this respect the great toe resembles the thumb. A small bursa is often interposed between the lateral side of the base of the first metatarsal bone and the medial side of the shaft of the second (fig. 571).

The bases of the second, third, fourth, and fifth metatarsal bones are connected by dorsal, plantar, and interosseous ligaments.

The heads of all the metatarsal bones are connected indirectly by the deep transverse ligaments of the sole.

The **dorsal** and **plantar ligaments** pass transversely between the bases of the adjacent bones.

The **interosseous ligaments** consist of strong transverse fibres which connect the rough non-articular portions of the adjacent surfaces (fig. 571).

Movements.—The movements permitted between the tarsal ends of the metatarsal bones are limited to a slight gliding of the articular surfaces one upon another when the anterior part of the foot is working under load (*cf.* movements of the intercuneiform joints, etc., p. 512).

THE SYNOVIAL CAVITIES OF THE TARSUS AND METATARSUS

The **synovial cavities** (fig. 571) present in the joints of the tarsus and metatarsus are six in number: one for the talocalcanean; a second for the talocalcaneonavicular; a third for the calcaneocuboid; a fourth for the cuneonavicular, intercuneiform, and cuneocuboid articulations, the articulations of the intermediate and lateral cuneiform bones with the bases of the second and third metatarsal bones, and the adjacent surfaces of the bases of the second, third, and fourth metatarsal bones; a fifth for the medial cuneiform bone with the metatarsal bone of the great toe; and a sixth, for the articulation of the cuboid bone with the fourth and fifth metatarsal bones. A small synovial cavity is sometimes found between the contiguous surfaces of the navicular and cuboid bones; it usually communicates with that between the cuboid and lateral cuneiform bones.

VIII. THE METATARSOPHALANGEAL JOINTS

The metatarsophalangeal joints are of the condyloid variety and are formed by the reception of the rounded heads of the metatarsal bones in shallow cavities on the bases of the proximal phalanges.

The *articular surfaces* cover the distal and plantar surfaces of the heads of the metatarsal bones but do not extend on to their dorsal surfaces. The plantar part of the head of the first metatarsal presents two longitudinal grooves separated by an intervening ridge. Each groove articulates with a sesamoid bone imbedded in the plantar ligament of the joint. The articular surface of the base of the proximal phalanx is concave in all diameters.

The ligaments of the joint are the capsular, plantar and collateral.

The **capsular ligaments** surround the joints and are attached to the margins of the articular surfaces. Dorsally, they are blended with the deep surfaces of the tendons of the long extensors, and they are inseparable from the deep surfaces of the plantar and collateral ligaments.

The **plantar (accessory plantar) ligaments** are thick, dense, fibrous structures. They are placed on the plantar surfaces of the joints in the intervals between the collateral ligaments, to which they are connected ; they are loosely united to the metatarsal bones, but are firmly fixed to the bases of the proximal phalanges. Their margins are continuous with the deep transverse ligaments of the sole, and their plantar surfaces are grooved for the flexor tendons, the fibrous sheaths of which are connected to the sides of the grooves ; the deep surfaces of the ligaments form parts of the articular facets for the heads of the metatarsal bones.

The **deep transverse ligaments of the sole** (ligamenta capitulorum transversa) consist of four short, wide, flattened bands which connect the plantar ligaments of adjoining metatarsophalangeal joints to one another. Their dorsal surfaces are related to the interosseous muscles and their plantar aspects to the lumbricals and the digital vessels and nerves. They correspond closely to the deep transverse ligaments of the palm (p. 477), but, in addition, they are connected to the plantar ligament of the first metatarsophalangeal joint.

The **collateral ligaments** are two strong, rounded cords, placed on the sides of the joints ; each is attached by one end to the dorsal tubercle on the side of the head of the metatarsal bone, and runs obliquely forwards and downwards to reach the corresponding side of the base of the phalanx.

The extensor tendons supply the place of *dorsal ligaments*.

Movements.—The active movements possible at the phalangeal joints are very similar to those permitted at the corresponding joints in the hand but are more limited in their range. Flexion is a much freer movement than extension and is usually associated with adduction. Abduction is possible only when the toes are extended (*cf.* p. 478). As in the hand, the *accessory movements* comprise gliding movements and rotation of the phalanges around their long axes.

Muscles producing the movements.—In **flexion,** the *flexor digitorum brevis*, the *lumbricals* and the *interossei* are the active agents, assisted by the flexor digitorum longus and the accessorius (quadratus plantæ). In the case of the little toe the *flexor digiti minimi brevis* assists, and in the case of the great toe the *flexores hallucis longus et brevis* are the only muscles concerned.

In **extension,** the *extensores digitorum longus et brevis* and the *extensor hallucis longus* are the only active agents.

In **adduction** and **abduction,** the line of reference passes through the second toe. The great toe is adducted by the *adductor hallucis*, and abducted by the *abductor hallucis*. The second toe is abducted to the medial side by the first dorsal interosseous muscle, and to the lateral side by the second. The third and fourth toes are abducted by the corresponding dorsal interossei and adducted by the first and second plantar interossei, respectively. The little toe is abducted by the abductor digiti minimi and adducted by the third plantar interosseous muscle.

IX. THE JOINTS OF THE DIGITS

The digital or interphalangeal joints are hinge-joints, and each has a capsular, a plantar and two collateral ligaments. The arrangement of these ligaments is similar to that in the metatarsophalangeal joints. The extensor tendons supply the places of dorsal ligaments.

Movements.—The only active movements permitted in the joints of the digits are flexion and extension ; these movements are freer between the proximal and middle phalanges than between the middle and distal. The amount of flexion is very considerable, but extension is limited by the tension of the flexor muscles and by the plantar ligaments.

The *accessory movements* comprise abduction, adduction and rotation.

Muscles producing the movements:

Flexion.—Flexores digitorum longus, brevis et accessorius (Quadratus plantæ), Flexor hallucis longus.

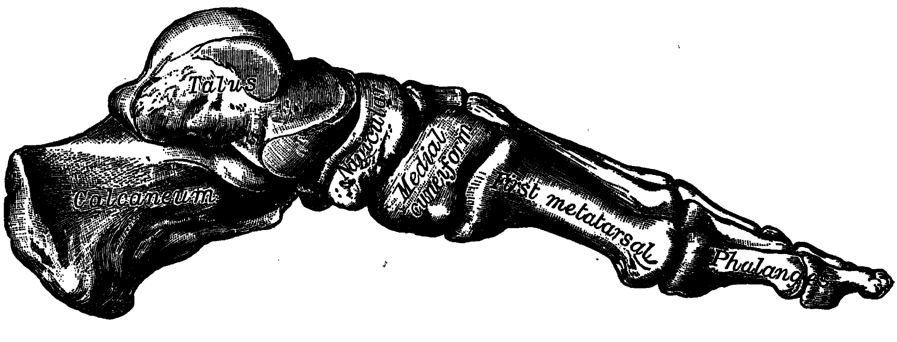
Extension.—Lumbricales, Interossei dorsales et plantares, Extensor hallucis longus.

The Arches of the Foot

The foot has two important functions to perform. (1) It must support the weight of the body in standing. (2) It must act as a lever to propel the body forwards in walking.

To fulfil the first function perfectly, the foot should lie flat on the ground and should be pliable enough to adapt itself to uneven surfaces. In actual

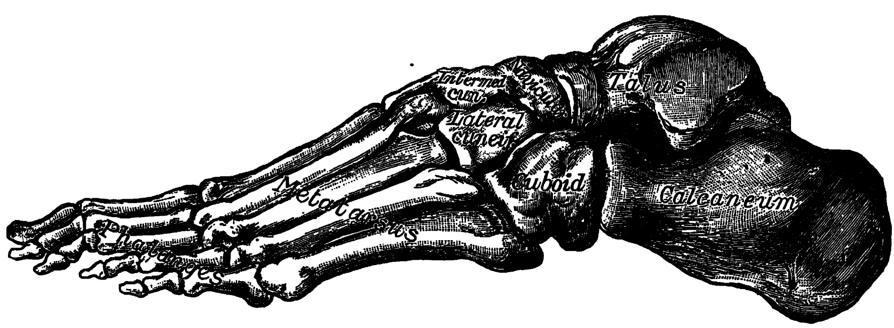
Fig. 572.—The skeleton of the left foot. Medial aspect.



fact, the foot of the child approaches this ideal much more nearly than the foot of the adult, which is, to a certain extent, permanently arched.

To fulfil its second function the foot must be capable of transformation into a rigid lever which will not collapse under the body weight. A segmented

Fig. 573.—The skeleton of the left foot. Lateral aspect.



lever, such as the foot, can only withstand stress if it is built up into an arch form, and in active use, therefore, the muscles acting on the foot convert it into a complex but rigid, arched lever. The arches thus formed comprise a longitudinal arch, which is divisible into a medial and a lateral portion, and a transverse arch. In the average adult these arches do not flatten out completely when the muscles are relaxed, and they are therefore to that extent permanent. They vary in height in different subjects.

The *medial arch* (fig. 572) is made up of the calcaneum, the talus, the navicular, the three cuneiform bones, and the first, second and third metatarsals. Its summit is at the superior articular surface of the talus, and its two extremities or piers, on which it rests on standing, are the tubercles on the plantar surface of the calcaneum posteriorly, and the heads of the first, second and

third metatarsal bones anteriorly. The chief characteristic of this arch is its resilience, due to its height and to the number of joints between its component parts. The arch is dependent for its maintenance on the tibialis posterior, the flexor digitorum longus and flexor hallucis longus muscles, assisted by the small muscles in the sole of the foot. Flattening of the arch is resisted by the tension of these muscles and by the plantar aponeurosis and the plantar ligaments of all the joints concerned, including the plantar calcaneonavicular or 'spring' ligament (p. 511).

The *lateral arch* (fig. 573) is composed of the calcaneum, the cuboid, and the fourth and fifth metatarsal bones. Its summit is at the talocalcanean articulation, and its chief joint is the calcaneocuboid, which allows only a limited movement. The most marked features of this arch are its solidity and its slight elevation; it is supported by the peroneus longus and the short muscles of the little toe, and its integrity is preserved by the long and short plantar ligaments.

In addition to the longitudinal arches the foot presents a series of *transverse arches*. At the posterior part of the metatarsus and the anterior part of the tarsus the arches are complete, but in the middle of the tarsus they present more the characters of half-domes the concavities of which are directed downwards and medially, so that when the medial borders of the feet are placed in apposition a complete tarsal dome is formed. The transverse arches are supported by the short muscles of the first and fifth toes (especially the transverse head of the adductor hallucis), and by the peroneus longus, the tendon of which stretches between the piers of the arches, and are strengthened by the interosseous and plantar ligaments.

It should be observed that in a normal foot the arches become flattened when the erect posture is assumed, and are restored when the weight of the body is taken off the feet. This resilience accounts for the suppleness of the normal foot and enhances the value of the arches by rendering possible such rapid and sudden movements as running and jumping.

In the resting upright posture the feet take up the position of eversion, but the first metatarsal and medial cuneiform bones are elevated and rotated upwards relative to the rest of the foot (p. 514). The latter movement is essential to allow the lateral border of the everted foot to remain in contact with the ground, and it results in a flattening of the transverse arch of the foot. The medial longitudinal arch appears to be more flattened than can be accounted for by the elevation of the first metatarsal bone. This is due to the fact that in eversion the arch rolls over, as it were, to the medial side, so that its concavity faces laterally and downwards instead of directly downwards.

When the posture is changed from the position of rest to one of activity, the foot becomes slightly inverted, the medial longitudinal arch is both apparently and actually raised and the transverse arch is accentuated by the action of the peroneus longus (p. 649). In this position the foot functions as an almost rigid but yet slightly resilient lever, as the full value of both arches can be utilised.

It should be observed that when the foot is on the ground it is not free to move round the talus in the movements of eversion and inversion, and these movements are brought about, in large part if not entirely, by a twisting of the talus on the rest of the foot. This twisting is the result of rotation of the lower limb, either at the knee or at the hip-joint, and is transmitted to the talus through the tibiofibular mortise.

Applied Anatomy.—In young children the foot appears to be completely flat in the resting upright posture, owing to the fact that it is everted at the subtalar joints and supinated at the first cuneometatarsal and cuneonavicular joints; during activity, however, the arched form of the foot becomes at once apparent. In most adults, on the other hand, the foot does not flatten completely in the resting upright posture, for, with increase of age, the arches become to some extent permanent structures. In some adults—particularly those with long and narrow feet—the foot appears to be abnormally flat in the resting posture, but the arches become apparent during activity. The functions of the foot are not impaired, but, despite this fact, these cases are often described as exhibiting a 'first degree flat foot.'

There are two varieties of flat foot associated with marked impairment of function. In the first the flat, everted position assumed during rest persists when the resting posture

is changed to one of activity, although the foot can still assume a normal arched form when not bearing weight. In this variety the deformity is purely postural and is due to loss of muscle tone and lack of muscular coordination. It is commonly associated with pain which is due to stretching of the plantar ligaments of the joints of the foot. The condition is often a local manifestation of a general postural deficiency, and its cure therefore depends upon correction of bad postural habits and re-education of the muscles.

In the second variety the flat, everted position of the foot becomes fixed as a result either of persistent muscle spasm or of joint stiffness following some inflammatory process. Such cases are described as 'rigid flat foot,' as the arched form of the foot cannot be produced even by passive movements.

MYOLOGY

MUSCULAR tissue is known to the layman as ' flesh ', and it is most familiar to him as the lean parts of a joint of meat. There are three varieties of muscular tissue : (1) *striped* or *voluntary*, (2) *unstriped* or *plain*, and (3) *cardiac*. The microscopical characters of these three varieties have been described in a previous section (pp. 32 to 36). This section deals only with voluntary muscle.

The individual fibres of voluntary muscle with their sheaths of *sarcolemma* (p. 32) are bound together into bundles or fasciculi by a connective tissue covering, termed the perimysium. Groups of fasciculi are in turn bound together by a similar but denser covering, termed the epimysium, and these groups form the individual *voluntary muscles* of the body. The voluntary muscles of the eyeball, ear, tongue, palate, larynx and pharynx are considered along with the anatomy of the organs concerned, but all the other voluntary muscles of the body will be included in this section.

All muscular tissue possesses the property of contractility, and movements of the body as a whole or of any of its parts are effected by the active contraction of a group or groups of voluntary muscles.

Attachments.—In order that a muscle may exercise its function of producing movements, it must be attached at both of its extremities. When a muscle contracts, one of its attachments remains relatively stationary, while the other is approximated to it. The term *origin* is used to designate the more fixed attachment and the term *insertion* to designate the movable point at which the force of the muscle is applied. As a general rule, so far as the limbs are concerned, the origin is the more proximal extremity of a muscle and the insertion the more distal. In accordance with these definitions the contraction of a muscle results in the approximation of its insertion to its origin, but the terms are arbitrary and used for convenience only, and it frequently happens that the contraction of a muscle may result in the approximation of its origin to its insertion. The Gluteus maximus provides an illustration of this fact. When it assists in extending the flexed thigh, its insertion into the gluteal tuberosity of the femur is then approximated to its origin from the dorsal surface of the sacrum. On the other hand, when the body is bent forwards at the hips, the Glutei maximi play the principal part in restoring it to the erect posture and, in this movement, the origin is approximated to the insertion.

The voluntary muscles are attached to the bones, cartilages, ligaments, skin or to other muscles, either directly or through the medium of fibrous structures called tendons and aponeuroses. Where a muscle is attached directly to bone or cartilage, the perimysium blends with the periosteum or perichondrium so that the fleshy fibres do not actually come into direct relation with the osseous or cartilaginous tissue, although they may appear to do so. Where muscle fibres are inserted into skin, e.g. the muscles of facial expression, they lie as a flattened layer on its deep surface and their perimysium blends with the subcutaneous areolar tissue. It may be noted that in such cases the insertion is incapable of becoming the fixed point, so that contraction always approximates the insertion to the bony origin.

Most muscles are provided with tendons at one or both extremities. *Tendons* are known to the layman as ' sinews ' or ' leaders ' ; they consist of white fibrous tissue (p. 10) and are usually cord- or band-like in appearance. In flat, sheet-like muscles which have a wide area of attachment a relatively thin but strong fibrous sheet takes the place of a cord-like tendon and is termed an *aponeurosis*. Where no tendon or aponeurosis can be seen with the naked eye, the attachment appears to be fleshy in character, but, as already stated, it is actually effected through the medium of the fusion of the perimysium with the periosteum or perichondrium.

Where one muscle is attached to another, the character of the connexion may be fleshy, tendinous or aponeurotic. (1) The fleshy fibres may interlace,

e.g. the mylohyoid muscles, and the perimysium of the one fuses with the perimysium of the other. (2) The two muscles may be connected by a common tendon. Such muscles are termed digastric and the two fleshy bellies are usually set at an angle which is maintained by a fascial loop thrown round the tendon from an adjoining bony point. (3) The two muscles may be connected by the interlacement of the fibres in their aponeuroses, e.g. the muscles of the abdominal wall.

Attachments of muscles exert a definite influence in the modelling of the bones of the skeleton and, when the attachment is tendinous in character, localised, elevated areas are usually present. On the other hand, when the muscle is attached by fleshy fibres the bony surface is smooth, and shows no corresponding elevations.

The muscles of the limbs with very few exceptions are inserted immediately distal to the joint on which they exert their principal action. This arrangement implies a loss of mechanical advantage, but what is lost in power is gained in the speed with which the hand or the foot, as the case may be, is moved over a wide range. For example, when the Brachialis muscle contracts, its insertion into the coronoid process of the ulna moves round an arc of a circle with a very short radius, but in the same period of time the hand moves round the corresponding arc of a circle whose radius is the length of the forearm and hand.

Muscular form.—The *form* of a muscle depends on the number and arrangement of its constituent fibres. When the fibres are arranged parallel or nearly parallel to what may be termed the 'line of pull' of the muscle, the full advantage of the muscular contractility is available and the maximum range is obtained. Such muscles may be *quadrilateral*, like the Thyrohyoid ; *fusiform*, like the Flexor carpi radialis ; or *straplike*, such as the Sartorius. If, on the other hand, the fibres are arranged obliquely in relation to the 'line of pull', the range is diminished, for the force of the muscular action can then be resolved into two components, one acting in the 'line of pull' and the other at right angles to it and therefore valueless so far as the range of the muscle is concerned. This oblique arrangement of the fibres is seen (*a*) in *unipennate* muscles such as the Flexor pollicis longus, in which the tendon of insertion extends upwards along one border of the muscle, (*b*) in *bipennate* muscles, such as the Rectus femoris, where the tendon extends upwards through the middle of the muscle, and (*c*) in *multipennate* muscles, such as the Deltoid, where a number of extensions pass upwards into the muscle from its tendon of insertion. The same arrangement is seen (*d*) in *triangular* muscles, such as the Temporalis, in which the muscular fibres converge on an apical tendon. As a rule the various forms of pennate and triangular muscles contain a larger number of fibres than fusiform, quadrilateral or straplike muscles, and they are found in situations where increased power is essential, because the power of a muscle is directly proportionate to the number of its constituent fibres.

Muscular contraction.—When a muscle is called on to participate actively in the production of a movement, all of its fibres are not necessarily thrown into contraction, for it adapts itself to the work which it is required to perform, and the more vigorous the effort demanded, the greater the number of fibres involved. During contraction a muscle fibre may shorten by thirty to forty per cent. of its uncontracted length.* As all the fibres in a given muscle are attached by one end to the tendon of origin, or its prolongation into the muscle, and by the other to the tendon of insertion, the maximum amount of shortening of the muscle is equal to the maximum amount of shortening of any one fibre, provided that all the fibres in the muscle are uniform in length, e.g. Sartorius. Owing to the rigidity of the bones, the amount of shortening possible is only a small percentage of the distance between the origin and the insertion, and the length of muscle fibres is adapted to their requirements. When, therefore, the muscle fibres are arranged parallel to the 'line of pull,' the muscular belly may be relatively short, and it is then provided with a long tendon—an arrangement which is both economical and efficient, for muscle tissue has a high metabolic rate and white fibrous tissue a low one.

* According to R. Wheeler Haines, *Journal of Anatomy*, vols. lxvi. and lxix., muscle fibres normally contract to 57 per cent. of their length when fully stretched.

Muscular actions.—Theoretically a muscle is capable of acting on every joint over which it passes, and the particular movements in which it takes part depend on the relationship of its 'line of pull' to the axes of the movements of the joint. For example, a muscle which passes in front of the transverse axis of the shoulder-joint will take part in the movement of flexion and, if it passes below the joint, it will also take part in adduction. It is movements, however, and not individual muscles which are represented in the cerebral cortex and it does not follow that a muscle will participate in a given movement because the mechanics of its attachments enable it to do so.

When a movement is carried out, a definite combination of muscles is called into play, and no muscle can be omitted nor can one be added, voluntarily. One muscle or more of the combination is the *prime mover*, and its active contraction necessarily involves the relaxation of its *antagonist*. The full effect, however, of the contraction of a prime mover can be obtained only when one of its attachments (usually the origin) is fixed; therefore, in the case of limb movements, every contraction of the prime movers is accompanied by the contraction of groups of *fixation muscles*. For example, the Deltoid is the prime mover in abduction of the arm and it can exert its full effect only when its clavicular and scapular origins are fixed. As a result abduction of the arm is always accompanied by contraction of muscles inserted into the scapula; and they are the fixation muscles for that movement. Some muscles pass over several joints, although they are prime movers of one joint only; and it may be necessary to counteract the effect of their action on the intermediate joints in the interests of efficiency. For this purpose a group of *synergic muscles* is brought into play. When the fist is clenched firmly, the prime movers are the flexors of the fingers, the flexors and adductor of the thumb and the Opponens pollicis muscle. The long flexors pass in front of the wrist-joint and are able to flex that joint, but only at the expense of the power with which they act on the digits. The extensors of the wrist, which are the synergic muscles for the movement, are therefore thrown into contraction in order to steady the wrist and obviate this loss of power. It should be observed, however, that there is no essential difference between fixation and synergic muscles, in so far as they both prevent waste of power and loss of efficiency on the part of the prime movers.

Under certain conditions the muscular groups which are called into play for some movements are profoundly altered by the action of gravity. When the body is in the erect posture flexion of the trunk is initiated by the ventral muscles, but thereafter the movement is carried out by the action of gravity, controlled and regulated by the Sacrospinales. The abducted arm is brought down to the side in a similar manner. In this instance the action of gravity is controlled by the Deltoid muscle, and the adductor muscles do not participate in the movement unless resistance is encountered.

It will now be apparent that the efficient performance of any movement depends on the proper co-ordination of prime movers, antagonists and fixation and synergic muscles, and this co-ordination is ensured by the manifold connexions which exist within the central nervous system.

Types of muscle fibres.—Many bivalves are provided with two distinct types of voluntary muscle. The one consists of pale fibres, which are capable of rapid contraction and have a high metabolic rate. They come into play to effect the closure of the shell. The other type consists of dark, red fibres, which contract more slowly and have a lower metabolic rate. They maintain the movement inaugurated by the pale fibres and their function is to keep the shell closed. In man and other vertebrates both pale and red fibres are present in all the voluntary muscles, but in varying proportions. It has been estimated that in some muscles, e.g. the Gastrocnemius, the pale fibres predominate, while in others, e.g. the Soleus, the red fibres are in the majority, and it has been suggested that some muscles are concerned with the initiation and performance of movements, while others are mainly postural, i.e. their function is to maintain the position so acquired.

Muscle tonus.—Living muscle never becomes fully relaxed, except under the influence of narcotic drugs, but is constantly in a condition of very slight contraction, the degree of which is subject to variation with the state of health

of the individual. This property of muscle tissue is termed 'muscle tonus,' and it has an important function to perform in connexion with posture. Thus the tonus of the deep muscles of the calf of the leg is responsible, to a very large extent, for the maintenance of the arches of the foot: the head is kept poised on the top of the vertebral column by the balance of the tonus of the flexor and extensor muscles: the abdominal viscera are maintained in place by the pressure exerted by the normal tonus of the abdominal muscles.

As a result of the possession of tonus, muscles have no slack to take in when they are required to contract, and movements can therefore be carried out without any initial lag.

THE TENDONS, APONEUROSES AND FASCIÆ

The **tendons** are tough, whitish cords, varying in length and thickness, and devoid of elasticity. They consist almost entirely of white fibrous tissue, the fibrils of which have an undulating course parallel with each other and are firmly united together. They are very sparingly supplied with blood-vessels, the smaller tendons having in their interior no trace of them. Nerves supplying tendons end in what are known as neurotendinous spindles or organs of Golgi; these are described with the organs of the senses.

The **aponeuroses** are flattened or expanded tendons, of a pearly-white colour, iridescent and often glistening; they are only sparingly supplied with blood-vessels.

The tendons and aponeuroses connect the muscles with the structures to be moved, such as the bones and cartilages. Where the end of a muscle is continued directly into a tendon, the line of junction between the two is usually well-defined, but where the muscle meets the tendon obliquely, bundles of tendon fibres generally run for a variable distance into the substance of the muscle, so that the line of junction is irregular. Microscopic examination shows that, in either case, the tendon is subdivided into small bundles, corresponding in size and number with the fibres of the muscle. Each muscular fibre ends in a more or less rounded extremity covered with sarcolemma, and the fibres of each tendon bundle are intimately united with the sarcolemma covering the end of the muscular fibre. The mode of union is well shown when the muscle fibre has shrunk inside its sarcolemma.

In situations where a muscle has to bend round a bony point to reach its insertion, the fleshy fibres cease before the change of direction begins so that the part subjected to pressure at the bend is tendinous in character. Friction is obviated by the provision of a synovial sheath or bursa (p. 428).

The **fasciæ** are fibro-areolar, membranous laminæ, of variable thickness and strength, found in all regions of the body, investing the softer and more delicate organs. During the process of development many of the cells of the mesoderm are differentiated into bones, muscles, vessels, etc.; the cells of the mesoderm which are not so utilised form an investment for these structures and are differentiated into the true skin and the fasciæ of the body. The fasciæ are subdivided into superficial and deep.

The *superficial fascia* is found immediately beneath the skin over the entire surface of the body. It connects the skin to the subjacent parts, and consists of fibro-areolar tissue, containing in its meshes pellicles of fat in varying quantity. It varies in thickness in different parts of the body; in the groin it is so thick that it may be subdivided into several laminæ. It facilitates the movement of the skin, serves as a soft bed for the passage of vessels and nerves to the skin, and retains the warmth of the body, since fat is a bad conductor of heat. Beneath the fatty layer there is generally another layer of superficial fascia, almost devoid of adipose tissue, in which the trunks of the subcutaneous vessels and nerves and the superficial lymph-glands are found. Certain cutaneous muscles are situated in the superficial fascia, e.g. the Platysma and the muscles of the face. The superficial fascia is most distinct at the lower part of the abdomen, in the perineum, and in the limbs; it is very thin on the dorsal aspects of the hands and feet, on the side of the neck, in the face, and around the anus. It is very dense in the scalp, palms of the hands, and soles

of the feet, forming a fibro-fatty layer which binds the skin firmly to the underlying structures.

The *deep fascia* is a dense, inelastic membrane, forming sheaths for the muscles, and in some cases affording them broad surfaces for attachment. It consists of bundles of white fibrous tissue, placed parallel with one another and connected together by other fibres disposed in a rectilinear manner. It forms a strong investment which not only binds down collectively the muscles in each region, but may give a separate sheath to each, and to the vessels and nerves as well. It assists the muscles in their actions by the degree of tension and pressure it makes upon their surfaces; in certain situations the degree of tension and pressure is regulated by muscles inserted into it, as, for instance, by the Tensor fasciæ latæ and Gluteus maximus in the thigh, and the Palmaris longus in the hand. In the limbs, the fascia not only invests the limb, but gives off septa which separate the various muscles, and are attached to the periosteum: these prolongations of fasciæ are usually spoken of as intermuscular septa.

In some situations the deep fascia shows a localised thickening, consisting largely of transversely running fibres. These are termed *retinacula* and they form retaining bands in the neighbourhood of the wrist and ankle joints to hold down the tendons. They are attached to the adjoining bony prominences and they help to form osteofibrous canals through which the tendons pass. When the muscles concerned contract vigorously, and bring about movements of the hand or foot, the tendons pull against the retinacula, which function as pulleys and serve to prevent loss of power. Synovial sheaths are provided for the tendons in these situations in order to obviate friction.

Similar fascial thickenings occur in the palm of the hand and the sole of the foot and on the flexor surfaces of the digits. In the first two situations, in addition to exercising a restraining effect on the tendons, they have a protective function.

The fasciæ and muscles may be grouped into those of the head and neck; of the trunk; of the upper limb; and of the lower limb.

THE FASCIÆ AND MUSCLES OF THE HEAD

I. The Muscles of Facial Expression

(*A*) *The Muscles of the Scalp*

Occipitofrontalis (Epicranius)

The **superficial fascia** in the scalp is a firm, fibro-fatty layer, intimately adherent to the skin, and to the underlying Occipitofrontalis muscle and its aponeurosis; behind, it is continuous with the superficial fascia at the back of the neck; laterally, it is prolonged into the temporal region, where it is looser in texture.

The **Occipitofrontalis** (Epicranius) is a broad, musculofibrous layer which covers the top of the skull, from the nuchal lines to the eyebrows. It consists of four bellies—two occipital and two frontal—connected by an intervening aponeurosis, termed the epicranial aponeurosis (galea aponeurotica).

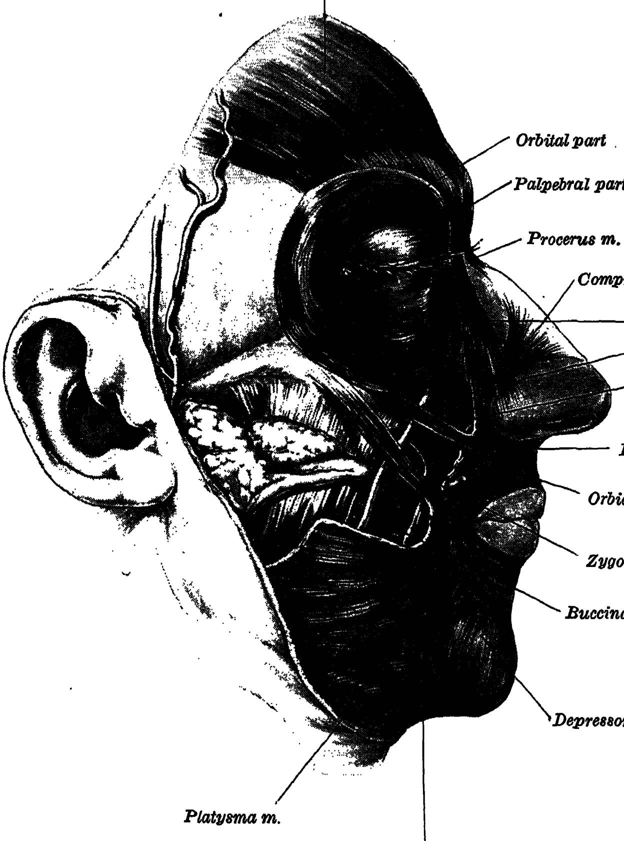
Each *Occipital belly*, thin and quadrilateral in form, arises by tendinous fibres from the lateral two-thirds of the highest nuchal line of the occipital bone, and from the mastoid part of the temporal bone. It ends in the epicranial aponeurosis.

Each *Frontal belly* (fig. 574) is thin, of a quadrilateral form, and intimately adherent to the superficial fascia. It is broader than the Occipital belly and its fibres are longer and paler in colour. It has no bony attachments. Its medial fibres are continuous with those of the Procerus; its intermediate fibres blend with the Corrugator and Orbicularis oculi; and its lateral fibres are also blended with the latter muscle over the zygomatic process of the frontal bone. From these attachments the fibres are directed upwards, and join the epicranial aponeurosis in front of the coronal suture. The medial margins of the Frontal bellies are joined together for some distance above the root of the nose; but

between the Occipital bellies there is a considerable, though variable, interval, occupied by an extension of the epicranial aponeurosis.

The **epicranial aponeurosis** (galea aponeurotica) (fig. 575) covers the upper part of the cranium; behind, it is attached, in the interval between the Occipital bellies, to the external occipital protuberance and highest nuchal line of the occipital bone; in front, it sends a short and narrow prolongation between the Frontal bellies. On each side it gives origin to the Auriculares anterior et superior; in this situation it becomes thinner, and is continued over the temporal

Fig. 574.—The muscles of the scalp and face. Right lateral aspect.



fascia to the zygomatic arch. It is closely united to the skin by the firm, fibro-fatty superficial fascia; it is connected to the pericranium by loose cellular tissue which allows of the movement of the epicranial aponeurosis, the latter carrying with it the skin of the scalp.

Nerve-supply.—The Occipital belly is supplied by the posterior auricular branch, and the Frontal belly by the temporal branches, of the facial nerve.

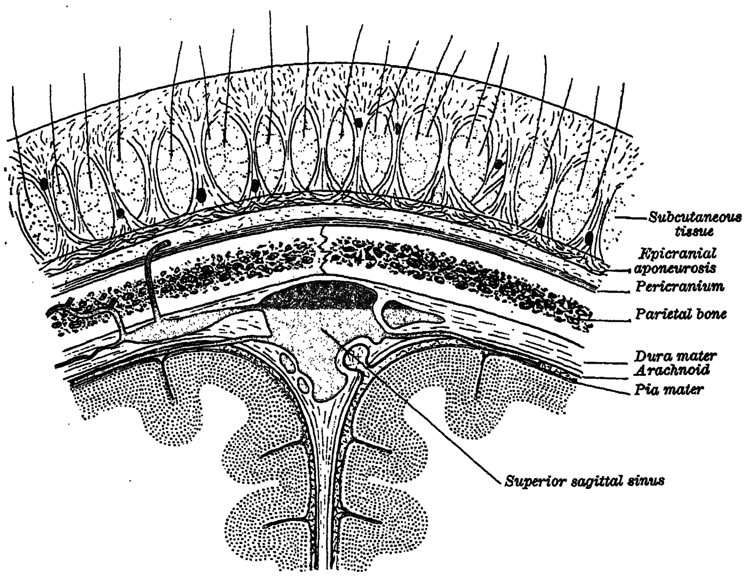
Actions.—The Occipital bellies draw the scalp backwards; the Frontal bellies acting from above raise the eyebrows and the skin over the root of the nose; acting from below they draw the scalp forwards, throwing the integument of the forehead into transverse wrinkles. The Occipital and Frontal bellies, acting alternately, move the entire scalp backwards and forwards. In the ordinary action of the Frontal bellies the eyebrows are elevated, thus giving to the face the expression of surprise: if the action be exaggerated, the eyebrows are

still further raised, and the skin of the forehead thrown into transverse wrinkles, as in the expression of fright or horror.

A thin muscular slip, termed the *Transversus nuchæ*, is present in about 25 per cent. of cases ; it arises from the external occipital protuberance or from the superior nuchal line, either superficial or deep to the Trapezius ; it is frequently inserted with the Auricularis posterior, but may join the posterior edge of the Sternomastoid.

Applied Anatomy.—The scalp consists of five layers, viz. the skin, subcutaneous tissue, Occipitofrontalis and its aponeurosis, subaponeurotic areolar tissue, and pericranium (fig. 575). But from a surgical standpoint it is better to regard the first three of these as a single layer, since they are all intimately united, and when torn off in an accident, or turned down as a flap in a surgical operation, remain firmly connected to each other. In consequence of the dense character of the subcutaneous tissue, the amount of swelling which

FIG. 575.—A coronal section through the scalp and skull. Diagrammatic.



occurs as the result of inflammation is slight ; and a wound which does not involve the Occipitofrontalis or its aponeurosis does not gape. The blood-vessels which lie in this tissue do not contract when wounded, and therefore the hæmorrhage from scalp wounds is often very considerable. It can, however, always be arrested by pressure—a matter of great importance, as, owing to the retraction of the cut ends, it is often very difficult or impossible to pick up with forceps a wounded vessel in the scalp.

The subaponeurotic areolar tissue is, from a surgical point of view, of considerable importance. It is loose and lax, and is easily torn through ; and hence, in wounds of the scalp, it is this tissue which is torn when the flap is separated from the parts beneath. The vessels are contained in the flap, and there is little risk of sloughing, unless the vitality of the part has been actually destroyed by the injury.

(*B*) *The Muscles of the Eyelids*

Levator palpebræ superioris. Orbicularis oculi. Corrugator.

The Levator palpebræ superioris is described with the anatomy of the eye.

The **Orbicularis oculi** (figs. 574, 576) is a broad, flat, elliptical muscle which occupies the eyelids, surrounds the circumference of the orbit, spreads over the temporal region, and downwards on the cheek. It consists of three main portions—orbital, palpebral and lacrimal.

The *orbital portion* of the Orbicularis oculi, of a reddish colour and thicker than the palpebral portion, arises from the nasal part of the frontal bone, from the frontal process of the maxilla (fig. 577), and from the medial palpebral

Fig. 576.—The left Orbicularis oculi. Posterior aspect.

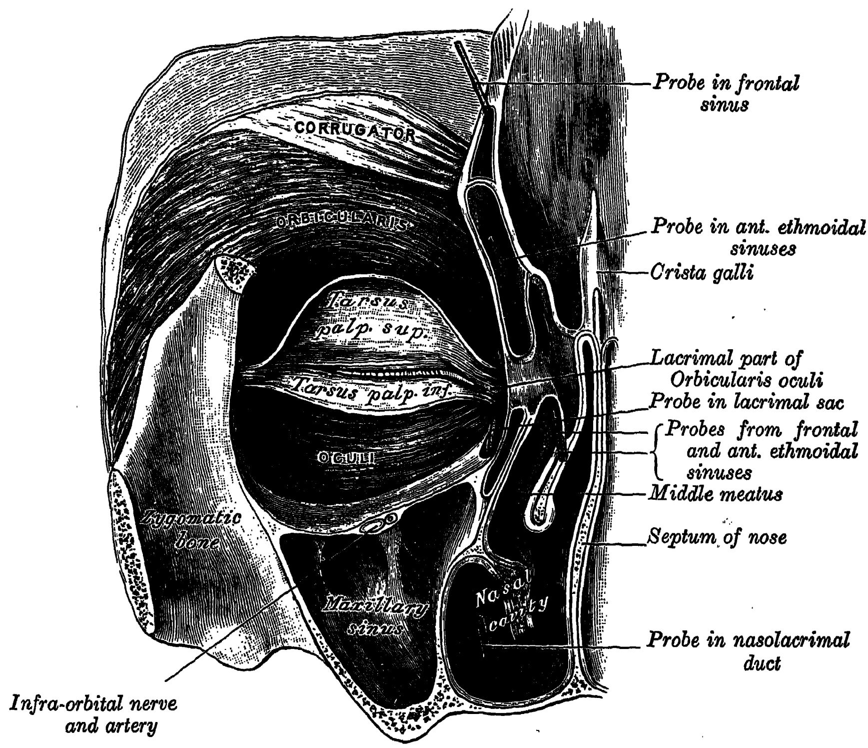
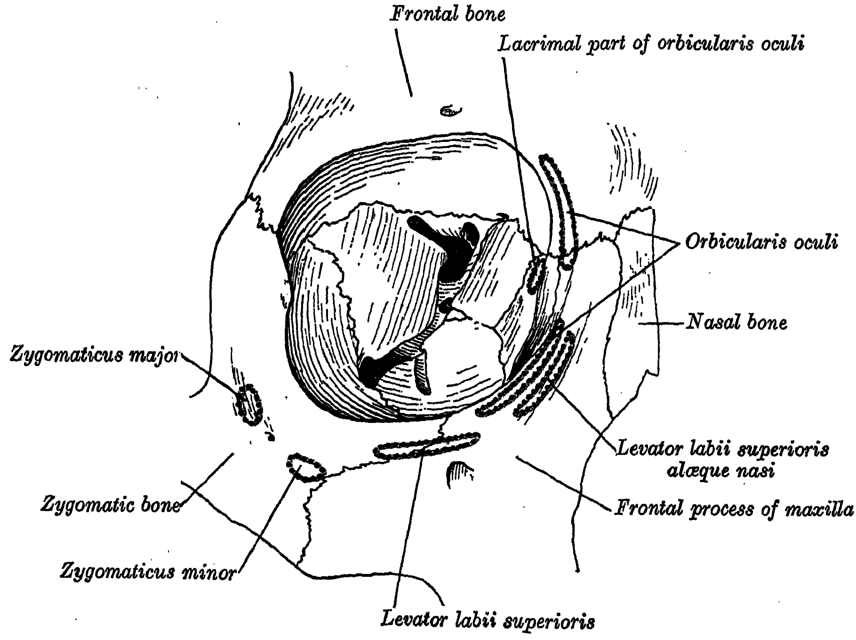


Fig. 577.—A sketch showing the attachments of the muscles around the right orbital opening.



ligament, which interrupts the line of the bony origin. Its fibres form complete ellipses without interruption on the lateral side, the upper fibres blending with the Frontal belly of Occipitofrontalis and the Corrugator.

The *palpebral portion* of the Orbicularis oculi is thin and pale ; it arises from the medial palpebral ligament, chiefly from its superficial and partly from its deep surface, but not from its lower margin ; it arises also from the bone immediately above and below the ligament. The muscular fibres sweep across the eyelids in front of the orbital septum and at the lateral commissure interlace to form the lateral palpebral raphe. A small bundle of very fine fibres lies close to the margin of each eyelid, behind the eyelashes ; it is named the *ciliary bundle.*

The *lacrimal portion* of the Orbicularis oculi (Tensor tarsi) lies behind the lacrimal sac, but is separated from it by the lacrimal fascia. It arises from the fascia covering the lacrimal sac, from the upper part of the crest of the lacrimal bone, and from the adjacent part of the lateral surface of the lacrimal bone (fig. 576). Passing laterally behind the lacrimal sac the muscle divides into an upper and a lower slip ; some of the fibres of these slips are inserted into the tarsi of the eyelids and are closely related to the lacrimal canaliculi, but most of them are continued across the eyelids in front of the tarsi and interlace in the lateral palpebral raphe.

The *medial palpebral ligament,* about 4 mm. in length and 2 mm. in breadth, is attached to the frontal process of the maxilla in front of the nasolacrimal groove. Crossing the lacrimal sac, it divides into an upper and a lower part, which are attached to the medial end of the corresponding tarsus. It is separated from the lacrimal sac by the lacrimal fascia.

The *lateral palpebral raphe* is a much weaker structure than the medial palpebral ligament. It is formed by the interlacing of the lateral ends of the palpebral fibres of the Orbicularis oculi, strengthened on its deep surface by the orbital septum. A few lobules of the lacrimal gland lie between it and the more deeply placed lateral palpebral ligament (Whitnall).

Nerve-supply.—The Orbicularis oculi is supplied by the temporal and zygomatic branches of the facial nerve.

Actions.—The Orbicularis oculi is the sphincter muscle of the eyelids. The palpebral portion acts involuntarily, closing the lids gently, as in sleep or in blinking ; the orbital portion is subject to the will. When the entire muscle is brought into action, the skin of the forehead, temple, and cheek is drawn towards the medial angle of the orbit, and the eyelids are firmly closed. The skin thus drawn upon is thrown into folds, especially radiating from the lateral angle of the eyelids ; these folds become permanent in old age, and form the so-called ' crow's feet.' The Levator palpebræ superioris is the direct antagonist of this muscle since it raises the upper eyelid and exposes the front of the bulb of the eye. The lacrimal part of the Orbicularis oculi draws the eyelids and the papillæ lacrimales medially, and directs them into the lacus lacrimalis ; at the same time it exerts traction on the lacrimal fascia and so dilates the lacrimal sac.

The **Corrugator** is a small pyramidal muscle, placed at the medial end of the eyebrow, deep to the Frontal belly of Occipitofrontalis and to the Orbicularis oculi. It arises from the medial end of the superciliary arch ; and its fibres pass laterally and slightly upwards, and are inserted into the deep surface of the skin, above the middle of the orbital arch.

Nerve-supply.—The Corrugator is supplied by the temporal branches of the facial nerve.

Actions.—The Corrugator draws the eyebrow medially and downwards, producing the vertical wrinkles of the forehead. It is the ' frowning ' muscle, and may be regarded as the principal muscle in the expression of suffering.

(*C*) *The Muscles of the Nose* (fig. 574)

Procerus.	Depressor septi.
Compressor naris.	Dilator naris.

The **Procerus** is a small pyramidal slip continuous with the medial part of the Frontal belly of the Occipitofrontalis. It arises from the fascia covering the

lower part of the nasal bone and the upper part of the upper nasal cartilage; it is inserted into the skin over the lower part of the forehead between the two eyebrows.

Actions.—The Procerus draws down the medial angle of the eyebrow and produces the transverse wrinkles over the bridge of the nose.

The **Compressor naris** (Nasalis, pars transversa) arises from the maxilla, above and lateral to the incisor teeth; its fibres proceed upwards and medially and expand into a thin aponeurosis, which is continuous on the bridge of the nose with that of the muscle of the opposite side, and with the aponeurosis of the Procerus.

Actions.—The Compressor naris compresses the nasal aperture at the junction of the vestibule with the nasal cavity.

The **Dilator naris** * (Nasalis, pars alaris) arises from the maxilla below and medial to the origin of the Compressor naris, and is inserted into the ala nasi.

Actions.—The Dilator naris draws the ala downwards and laterally, and so assists in widening the anterior nasal aperture.

The **Depressor septi**, which is often regarded as a constituent portion of the Dilator naris, arises from the maxilla above the central incisor tooth; its fibres ascend to be inserted into the septum mobile nasi. It lies between the mucous membrane and muscular structure of the lip.

Actions.—The Depressor septi assists the Dilator naris to widen the nasal aperture.

Nerve-supply.—All the muscles of this group are supplied by the upper buccal branches of the facial nerve.

(*D*) *The Muscles of the Mouth* (fig. 574)

Levator labii superioris alæque nasi.†	Mentalis.
Levator labii superioris.†	Depressor labii inferioris.
Zygomaticus minor.†	Depressor anguli oris.
Levator anguli oris.	Buccinator.
Zygomaticus major.	Orbicularis oris.

Risorius.

The **Levator labii superioris alæque nasi** † arises from the upper part of the frontal process of the maxilla, and passing obliquely downwards and laterally divides into medial and lateral slips. The medial slip is inserted into the lower nasal cartilage (greater alar cartilage) and skin of the nose; the lateral slip is prolonged into the lateral part of the upper lip, and blends with the Levator labii superioris and with the Orbicularis oris.

Actions.—The lateral slip raises and everts the upper lip; the medial slip acts as a dilator of the nostril.

The **Levator labii superioris** † arises from the lower margin of the orbital opening immediately above the infra-orbital foramen, some of its fibres arising from the maxilla and others from the zygomatic bone. Its fibres converge to be inserted into the muscular substance of the upper lip between the lateral slip of the Levator labii superioris alæque nasi and the Levator anguli oris.

Actions.—The Levator labii superioris raises and everts the upper lip. It assists the Zygomaticus minor to form the nasolabial furrow, which passes from the side of the nose to the upper lip and gives to the face an expression of sadness.

The **Zygomaticus minor** † arises from the lateral surface of the zygomatic bone immediately behind the zygomaticomaxillary suture, and passes downwards and medially to be inserted into the muscular substance of the upper lip. It is separated from the Levator labii superioris by a narrow interval (fig. 574).

Actions.—The Zygomaticus minor assists in elevating the upper lip and in the production of the nasolabial furrow. When the Levator labii superioris

* The Dilatatores naris (B.N.A.) are represented by a few, poorly developed muscular slips which arise from the margin of the anterior bony aperture of the nose and the adjoining nasal cartilages and are inserted into the skin near the margin of the nostril.

† In the B.N.A. the Levator labii superioris alæque nasi, the Levator labii superioris and the Zygomaticus minor are grouped together and are termed the *angular*, *infra-orbital* and *zygomatic heads*, respectively, of the Quadratus labii superioris.

alæque nasi, the Levator labii superioris and the Zygomaticus minor are in action together they give to the countenance the expression of contempt and disdain.

The **Levator anguli oris** (Caninus) arises from the canine fossa, just below the infra-orbital foramen, and is inserted into the angle of the mouth, intermingling with the fibres of the Zygomaticus major, Depressor anguli oris (Triangularis), and Orbicularis oris. Between the Levator anguli oris and the Levator labii superioris are the infra-orbital vessels and plexus of nerves.

Actions.—The Levator anguli oris raises the angle of the mouth and assists in producing the nasolabial furrow.

The **Zygomaticus major** (Zygomaticus) arises from the zygomatic bone, in front of the zygomatico-temporal suture, and is inserted into the angle of the mouth, where it blends with the fibres of the Levator anguli oris (Caninus), Orbicularis oris, and Depressor anguli oris (Triangularis).

Actions.—The Zygomaticus major draws the angle of the mouth upwards and laterally as in laughing.

Nerve-supply.—All the five preceding muscles are supplied by the buccal branches of the facial nerve.

The **Mentalis** is a conical fasciculus, situated at the side of the frenulum of the lower lip. It arises from the incisive fossa of the mandible and descends to be inserted into the skin of the chin.

Actions.—The Mentalis raises and protrudes the lower lip, and at the same time wrinkles the skin of the chin, expressing doubt or disdain.

The **Depressor labii inferioris** (Quadratus labii inferioris) is a quadrilateral muscle. It arises from the oblique line of the mandible, between the symphysis menti and the mental foramen, and passes upwards and medially, to be inserted into the skin of the lower lip, its fibres blending with those of its fellow of the opposite side and with the Orbicularis oris. At its origin it is continuous with the fibres of the Platysma. Much yellow fat is intermingled with the superficial fibres of this muscle.*

Actions.—The Depressor labii inferioris draws the lower lip downwards and a little laterally, as in the expression of irony.

The **Depressor anguli oris** (Triangularis) arises from the oblique line of the mandible, below and lateral to the Depressor labii inferioris ; its fibres converge and are inserted by a narrow fasciculus into the angle of the mouth. At its origin it is continuous with the Platysma, and at its insertion with the Orbicularis oris and Risorius ; some of its fibres are directly continuous with those of the Levator anguli oris (Caninus), and others are occasionally found crossing from the muscle of one side to that of the other ; these latter fibres constitute the *Transversus menti.*

Actions.—The Depressor anguli oris draws the angle of the mouth downwards and laterally.

Nerve-supply.—The Mentalis, the Depressor labii inferioris and the Depressor anguli oris are all supplied by the mandibular branch of the facial nerve.

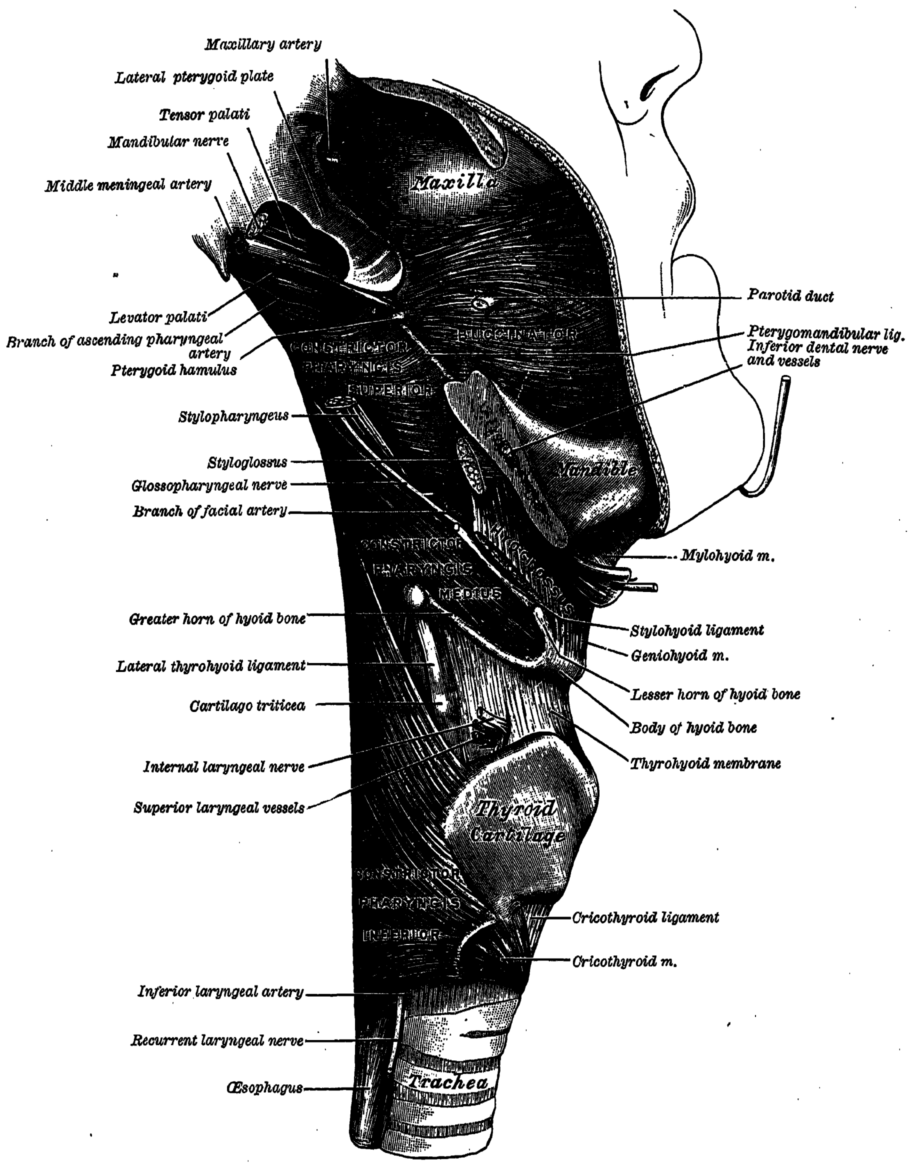
The **Buccinator** (fig. 578) is a thin quadrilateral muscle, occupying the interval between the maxilla and the mandible, at the side of the face. It arises from the outer surfaces of the alveolar processes of the maxilla and mandible, opposite to the three molar teeth ; and, behind, from the anterior border of the pterygomandibular ligament (pterygomandibular raphe), which separates the muscle from the Superior constrictor of the pharynx. Between the tuberosity of the maxilla and the upper end of the pterygomandibular ligament, a few fibres arise from a fine tendinous band which bridges the interval between the maxilla and the pterygoid hamulus. The tendon of the Tensor palati on its way to the soft palate pierces the pharyngeal wall in the small gap which lies behind this tendinous band. The fibres of the Buccinator converge towards the angle of the mouth, where the central fibres intersect each other, those from below being continuous with the upper segment of the Orbicularis oris, and

* The Zygomaticus major and minor and the Levator labii superioris are sometimes more or less concealed by a thin sheet of muscle, named the *Musculus malaris,* and continuous with the Orbicularis oculi. (Consult an article on the facial muscles, etc., by G. H. S. Lightoller, *Journal of Anatomy,* vol. lx. 1925.)

those from above with the lower segment; the highest and lowest fibres are continued forward into the corresponding lip without decussation.

Relations.—The Buccinator is on the same plane as the Superior Constrictor of the pharynx and is covered by the buccopharyngeal fascia. It is in relation by its *superficial surface*, behind, with a large mass of fat, which separates it from the ramus of the mandible,

FIG. 578.—The Buccinator and the muscles of the pharynx.



the Masseter and a small portion of the Temporalis; this fat has been named the *suctorial pad*, because it is supposed to assist in the act of sucking. In front the superficial surface of the Buccinator is in relation with the Zygomaticus major, Risorius, Levator and Depressor anguli oris, and the parotid duct, which pierces it opposite the second molar tooth of the maxilla; the facial (external maxillary) artery and anterior facial vein cross it from below upwards; it is also crossed by branches of the facial and buccal nerves. The *deep surface* is in relation with the buccal glands and mucous membrane of the mouth.

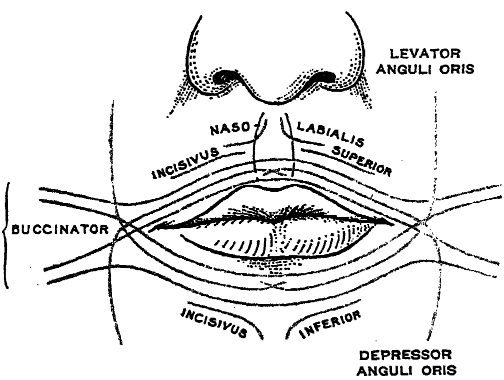
Nerve-supply.—The Buccinator is supplied by the lower buccal branches of the facial nerve.

Actions.—The Buccinator muscles compress the cheeks against the teeth, so that during the process of mastication the food is kept under the immediate pressure of the teeth. When the cheeks have been previously distended with air, the Buccinators expel it between the lips, as in blowing a trumpet; hence the name (*buccina*, a trumpet).

The *pterygomandibular ligament* (pterygomandibular raphe) is a tendinous band which is attached by one extremity to the hamulus of the medial pterygoid plate, and by the other to the posterior end of the mylohyoid line of the mandible. *Medially* it is covered by the mucous membrane of the mouth. *Laterally* it is separated from the ramus of the mandible by a quantity of adipose tissue. *Posteriorly* it gives attachment to the Superior constrictor of the pharynx, and *anteriorly* to a part of the Buccinator (fig. 578).

The **Orbicularis oris** (figs. 574, 579) is not a simple sphincter muscle like the Orbicularis oculi; it is made up of several strata of fibres which surround the orifice of the mouth but have different directions. It consists partly of fibres derived from the other facial muscles which are inserted into the lips, and partly of fibres proper to the lips. Of the former, a considerable number are derived from the Buccinator, and form the deeper stratum of the Orbicularis. Some of the Buccinator fibres—namely, those near the middle of the muscle—decussate at the angle of the mouth; the uppermost and lowermost fibres pass across the lips from side to side without decussation. Superficial to this is a second stratum, formed by the Levator and Depressor anguli oris (Caninus and Triangularis), which cross each other at the angle of the mouth; the fibres from the Levator pass to the lower lip, and those from the Depressor to the upper lip, along which they run, to be inserted into the skin near the anterior median line. Fibres are also derived from the Levator labii superioris, the Zygomaticus major and minor, and the Depressor labii inferioris (Quadratus labii inferioris); these intermingle with the transverse fibres described above, and have principally an oblique direction. The proper fibres of the lips are oblique, and pass from the deep surface of the skin to the mucous membrane, through the thickness of the lip. Finally there are fibres by which the muscle is connected with the maxillæ and the septum of the nose, above, and with the mandible, below. In the upper lip these consist of two bands, lateral and medial, on each side; the lateral band (*m. incisivus labii superioris*) arises from the alveolar border of the maxilla, opposite the lateral incisor tooth, and arching laterally is continuous with the other muscles at the angle of the mouth; the medial band (*m. nasolabialis*) connects the upper lip to the back of the septum of the nose. The interval between the two medial bands corresponds with the depression, called the *philtrum*, seen on the upper lip below the septum of the nose. The additional fibres for the lower lip constitute a slip (*m. incisivus labii inferioris*) on each side; this slip arises from the mandible, lateral to the Mentalis, and mingles with the other muscles at the angle of the mouth.

FIG. 579.—A scheme showing the arrangement of the fibres of the Orbicularis oris.



Nerve-supply.—The Orbicularis oris is supplied by the lower buccal and the mandibular branches of the facial nerve.

Actions.—The Orbicularis oris in its ordinary action effects the direct closure of the lips; by its deep, assisted by its oblique, fibres, it compresses the lips against the teeth. The superficial part, consisting principally of the decussating fibres, brings the lips together and protrudes them.

The **Risorius** arises from the parotid fascia and is inserted into the skin at

the angle of the mouth (fig. 574). It is a narrow bundle of fibres, broadest at its origin, but varying much in its size and form.

Nerve-supply.—The Risorius is supplied by the buccal branches of the facial nerve.

Actions.—The Risorius retracts the angle of the mouth, and produces an unpleasant grinning expression.*

II. The Muscles of Mastication

Masseter.	Pterygoideus lateralis.
Temporalis.	Pterygoideus medialis.

A strong layer of fascia, derived from the deep cervical fascia and named the **parotid fascia**, covers the Masseter and is firmly connected with it. It is attached to the lower border of the zygomatic arch, and invests the parotid gland (p. 536).

The **Masseter** (fig. 586) is a quadrilateral muscle, consisting of two portions, superficial and deep. The *superficial portion*, the larger, arises by a thick aponeurosis from the zygomatic process of the maxilla, and from the anterior two-thirds of the lower border of the zygomatic arch ; its fibres pass downwards and backwards, to be inserted into the angle and lower one-half of the lateral surface of the ramus of the mandible. The *deep portion* is much smaller and is partly concealed by the superficial portion ; it arises from the posterior one-third of the lower border and from the whole of the medial surface of the zygomatic arch ; its fibres pass almost vertically downwards to be inserted into the lateral surfaces of the coronoid process and the upper one-half of the ramus of the mandible.

Relations.—*Superficial* to the muscle are the integument, the Platysma, the Risorius, the Zygomaticus major, and the parotid gland ; the parotid duct, branches of the facial nerve, and the transverse facial vessels cross the muscle. The *deep surface* is in relation with the insertion of the Temporal muscle and the ramus of the mandible ; a mass of fat separates it in front from the Buccinator muscle and the buccal nerve. The masseteric nerve and artery reach the deep surface of the muscle by passing through the posterior part of the mandibular notch. The *posterior margin* is overlapped by the parotid gland ; the *anterior margin* projects over the Buccinator and is crossed below by the anterior facial vein.

Nerve-supply.—The Masseter is supplied by a branch of the anterior trunk of the mandibular nerve.

Actions.—The Masseter pulls the mandible towards and against the maxillæ ; from its relation to the axis of movement it can act with very great force.

The **temporal fascia** covers the Temporal muscle. It is a strong, fibrous investment, covered, laterally, by the Auriculares anterior et superior, the epicranial aponeurosis, and part of the Orbicularis oculi. The superficial temporal vessels and the auriculotemporal nerve cross it from below upwards. Above, it is a single layer, attached to the entire extent of the superior temporal line ; below, it consists of two layers, one of which is attached to the lateral, and the other to the medial border of the zygomatic arch. A small quantity of fat, the zygomatic branch of the superficial temporal artery, and the zygomatico-temporal branch of the maxillary nerve, are contained between these two layers. The deep surface of the fascia affords attachment to the superficial fibres of the Temporalis.

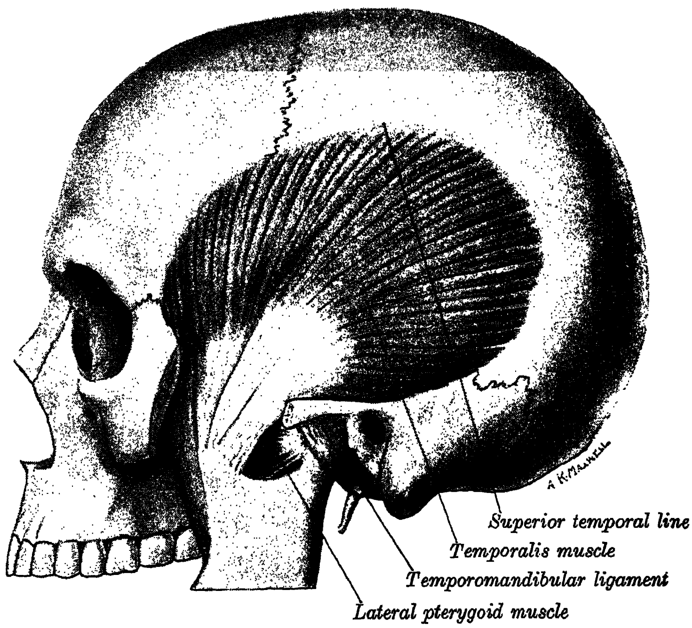
The **Temporalis** (fig. 580) is a fan-shaped muscle, situated at the side of the head. It arises from the whole of the temporal fossa (except the portion formed by the zygomatic bone) and from the deep surface of the temporal fascia. Its fibres converge as they descend, and end in a tendon which passes through the gap between the zygomatic arch and the side of the skull, and is inserted into the medial surface, apex, and anterior border of the coronoid process, and the

* Lightoller (*loc. cit.*) gives a detailed description of a *knot* or localised thickening where the fibres of the muscles surrounding or running to the oral fissure meet and intermingle. This knot is placed about 1 cm. lateral to the angle of the mouth, and has the form of a flattened cone with its base on the mucous membrane of the mouth ; the base, which is crescentic, has a vertical measurement of about 4 cm., and curves forward for a short distance into the lips.

anterior border of the ramus of the mandible nearly as far forwards as the last molar tooth.

Relations.—*Superficial* to the muscle are the skin, the Auriculares anterior et superior, the temporal fascia, the superficial temporal vessels, the auriculotemporal nerve, the temporal branches of the facial nerve, the zygomaticotemporal nerve, the epicranial aponeurosis, the zygomatic arch, and the Masseter. The *deep surface* is in relation with the temporal fossa, the Lateral pterygoid and part of the Buccinator, the maxillary artery and its deep temporal branches, the deep temporal nerves, and the buccal vessels and nerve. *Behind* the tendon of the muscle the vessels and nerve to the Masseter traverse the mandibular notch. The *anterior border* is separated from the zygomatic bone by a mass of fat.

FIG. 580.—The left Temporalis muscle. The zygomatic arch and the Masseter muscle have been removed.



Nerve-supply.—The Temporalis is supplied by the deep temporal branches of the anterior trunk of the mandibular nerve.

Actions.—The Temporal muscle elevates the mandible and so closes the mouth. This movement requires both the upward pull of the anterior fibres and the backward pull of the posterior fibres, because the head of the mandible rests on the articular eminence when the mouth is open. The posterior fibres draw the mandible backwards after it has been protruded.

The **Pterygoideus lateralis** (Pterygoideus externus) (fig. 581) is a short, thick muscle, somewhat conical in form. It arises by two heads : an *upper* from the infratemporal surface and infratemporal crest of the greater wing of the sphenoid bone ; and a *lower* from the lateral surface of the lateral pterygoid plate. Its fibres pass backwards and laterally, to be inserted into a depression on the front of the neck of the mandible, and into the articular capsule and disc of the mandibular articulation.

Relations.—Its *superficial surface* is in relation with the ramus of the mandible, the maxillary artery, which crosses it,* the tendon of the Temporal muscle and the Masseter. Its *deep surface* rests against the upper part of the Pterygoideus medialis, the sphenomandibular ligament, the middle meningeal artery, and the mandibular nerve ; its *upper border* is in relation with the temporal and masseteric branches of the mandibular nerve ; its *lower border* with the lingual and inferior dental (alveolar) nerves. The buccal (buccinator) nerve and the maxillary artery pass between the heads of the muscle.

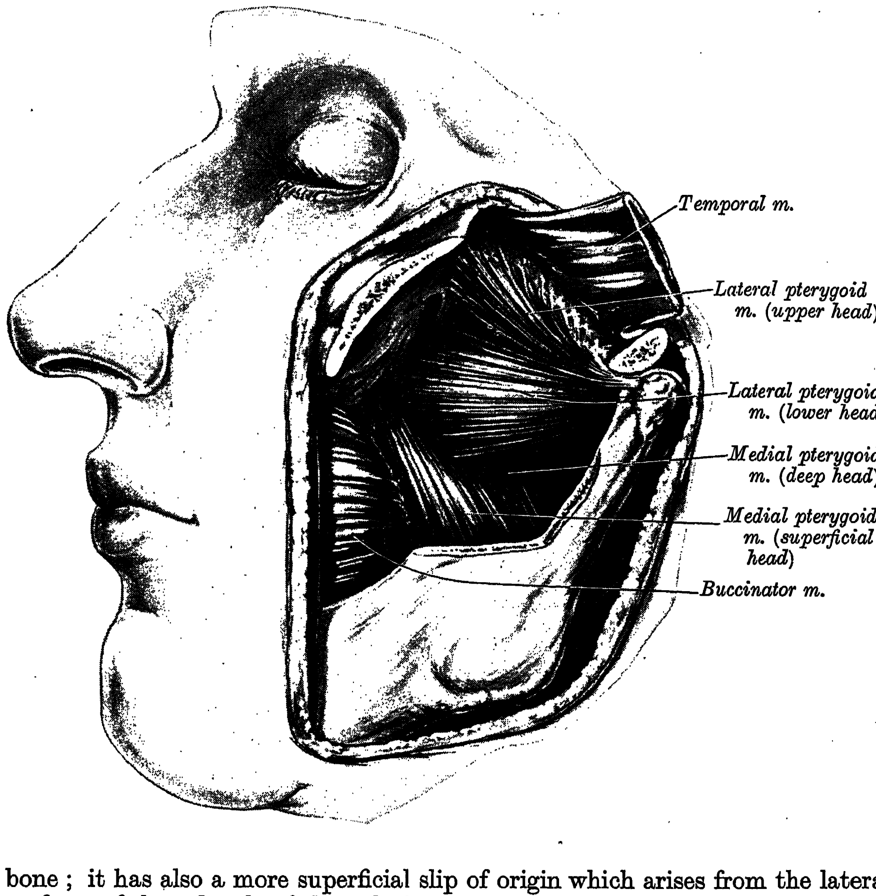
Nerve-supply.—The Lateral pterygoid muscle is supplied by a branch from the anterior trunk of the mandibular nerve.

* The artery often lies deep to the muscle, as shown in Fig. 582.

Actions.—The Lateral pterygoid muscle assists in opening the mouth, by pulling forward the condyloid process of the mandible and the articular disc, while the body of the mandible is being depressed by the suprahyoid muscles. Acting with the Medial pterygoid muscle it protrudes the mandible so that the lower incisors are projected in front of the upper.

The **Pterygoideus medialis** (Pterygoideus internus) (fig. 581), a thick, quadrilateral muscle, arises from the medial surface of the lateral pterygoid plate, and from the grooved surface of the tubercle (pyramidal process) of the palatine

Fig. 581.—The left Pterygoid muscles. The zygomatic arch and a portion of the ramus of the mandible have been removed.



bone; it has also a more superficial slip of origin which arises from the lateral surfaces of the tubercle of the palatine bone and tuberosity of the maxilla, and lies at first on the surface of the lower part of the lower head of the Lateral pterygoid muscle. Its fibres pass downwards, laterally, and backwards, and are inserted, by a strong tendinous lamina, into the lower and back part of the medial surfaces of the ramus and angle of the mandible, as high as the mandibular foramen.

Relations.—The *lateral surface* of the muscle is in relation with the ramus of the mandible, from which it is separated, at its upper part, by the Lateral pterygoid, the sphenomandibular ligament, the maxillary artery, the inferior dental vessels and nerve, the lingual nerve, and a process of the parotid gland. The *medial surface* is in relation with the Tensor palati, and is separated from the Superior constrictor of the pharynx by the Styloglossus, the Stylopharyngeus and some areolar tissue.

Nerve-supply.—The Medial pterygoid muscle is supplied by a branch from the mandibular nerve.

Actions.—The Medial pterygoid muscle assists in approximating the mandible to the maxillæ. Acting with the Lateral pterygoid it protrudes the

mandible. When the two Pterygoid muscles of one side are in action, the corresponding side of the mandible is drawn forwards, while the head of the mandible on the opposite side remains comparatively fixed ; by an alternating action of the muscles of the two sides, the side-to-side movements, such as take place during trituration of the food, are effected.

Fig. 582.—The structures in relation with the left Pterygoid muscles.

The **Pterygospinous ligament**, which is occasionally replaced by muscle fibres, stretches between the spine of the sphenoid bone and the posterior border of the lateral pterygoid plate near its upper end. It is sometimes ossified and then helps to bound a foramen which transmits the branches of the mandibular nerve destined for the Temporal, Masseter and Lateral pterygoid muscles.

THE FASCIÆ AND MUSCLES OF THE ANTEROLATERAL REGION OF THE NECK

The anterolateral muscles of the neck may be arranged into the following groups :

I. Superficial and lateral cervical.	III. Anterior vertebral.
II. Supra- and infra-hyoid.	IV. Lateral vertebral.

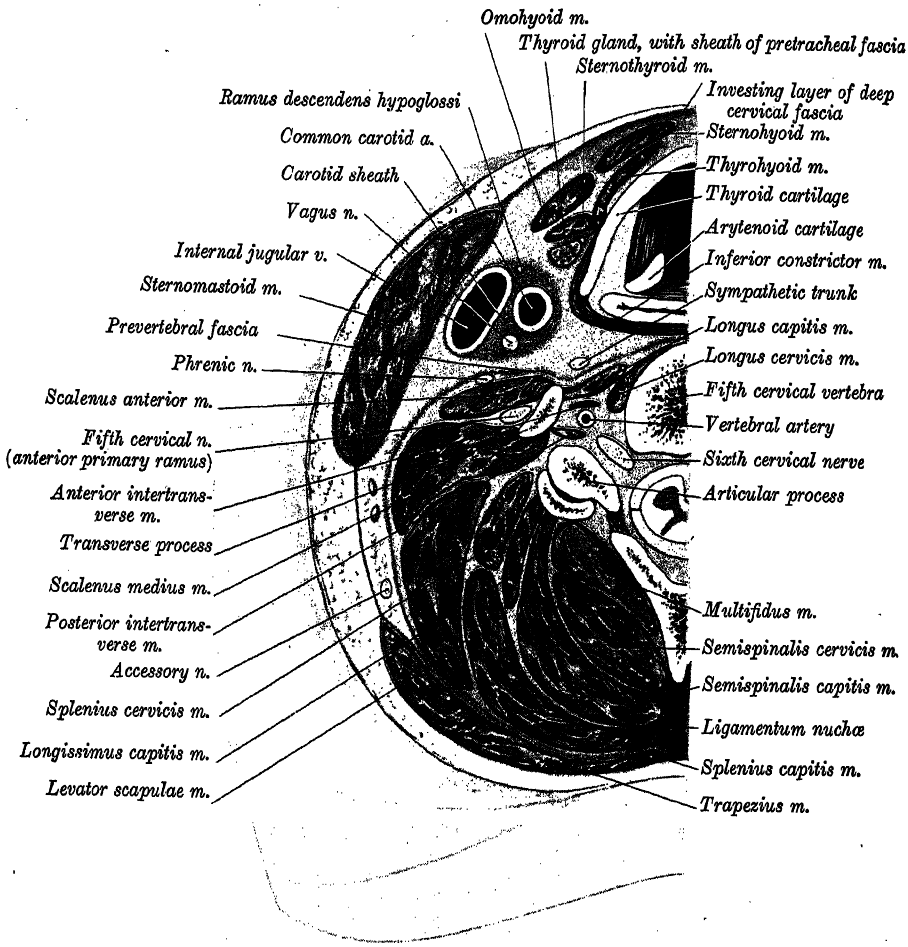
The **superficial fascia** of the neck is a thin lamina investing the Platysma and is hardly demonstrable as a separate membrane.

The **deep cervical fascia** (fig. 583) lies under cover of the Platysma, and invests the muscles of the neck. It consists of fibro-areolar tissue which occupies all the intervals that would otherwise exist between the muscles, viscera, vessels, etc., of the neck. In certain situations the white fibres predominate, and the fascia assumes the form of a thin fibrous sheet or layer, but elsewhere the tissue is loosely arranged and is easily broken down. It becomes condensed

around the blood-vessels, providing them with fibrous sheaths which here, as elsewhere in the body, bind the arteries and their accompanying veins closely together.

The investing portion of the fascia is attached behind to the ligamentum nuchæ and to the spine of the seventh cervical vertebra. It forms a thin investment for the Trapezius, and from the anterior border of this muscle is continued forwards, as a rather loose areolar layer covering the posterior triangle of the neck, to the posterior border of the Sternomastoid, where it

FIG. 583.—A transverse section through the left half of the neck to show the arrangement of the deep cervical fascia. Semidiagrammatic.



begins to assume the appearance of a fascial membrane. Along the hinder edge of the Sternomastoid it divides to enclose the muscle, and at the anterior margin again forms a single lamella, which covers the anterior triangle of the neck and reaches forwards to the median plane, where it is continuous with the corresponding lamella from the opposite side of the neck. In the median plane of the neck it is fixed to the symphysis menti and the body of the hyoid bone.

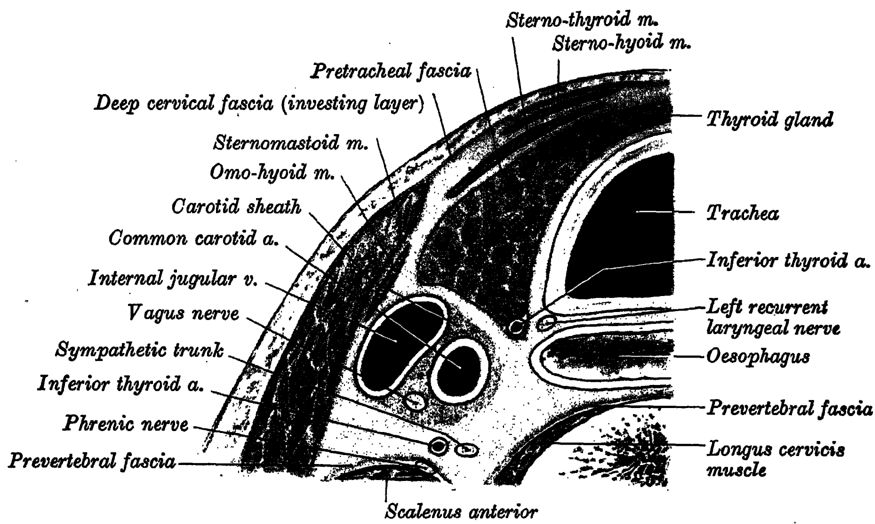
Above, the fascia is attached to the superior nuchal line of the occipital bone, to the mastoid process of the temporal bone, and to the whole length of the base of the mandible. Opposite the angle of the mandible it is very strong, and binds the anterior edge of the Sternomastoid firmly to that bone. Between the mandible and the mastoid process it ensheathes the parotid gland—the layer which covers the gland extends upwards under the name of the *parotid fascia*

and is fixed to the zygomatic arch. From the part which passes deep to the parotid gland a strong band ascends to the styloid process, forming the *stylo-mandibular ligament* (p. 433).

Below, the fascia is attached to the acromion, the clavicle and the manubrium sterni. Some little distance above the last, it splits into a superficial and a deep layer. The former is attached to the anterior border of the manubrium, the latter to its posterior border and to the interclavicular ligament. Between these two layers there is a slit-like interval, termed the *suprasternal space* ; it contains a small quantity of areolar tissue, the lower portions of the anterior jugular veins and the jugular arch, the sternal heads of the Sternomastoid muscles, and sometimes a lymph-gland.

The *carotid sheath* is a condensation of the cervical fascia in which the common and internal carotid arteries, the internal jugular vein, the vagus nerve and the constituents of the ansa hypoglossi are imbedded. It is thicker on the arteries than it is on the vein, and peripherally it is connected to the neighbouring layers by loose areolar tissue (fig. 584).

FIG. 584.—Part of a transverse section through the lower part of the neck to show the carotid sheath. Semidiagrammatic.



The *prevertebral layer* of the cervical fascia covers the prevertebral muscles and extends laterally on the Scalenus anterior, the Scalenus medius and the Levator scapulæ muscles, i.e. it forms a fascial floor for the posterior triangle of the neck. As the subclavian artery and the brachial nerves emerge from behind the Scalenus anterior they carry the prevertebral fascia downwards and laterally behind the clavicle to form the *axillary sheath.* Traced laterally round the neck, the prevertebral fascia rapidly becomes thinner and more areolar in character and it is lost as a definite fibrous layer under cover of the Trapezius. Superiorly it is attached to the base of the skull, and inferiorly it is carried downwards in front of the longus cervicis (longus colli) muscles into the superior mediastinum, where it blends with the anterior longitudinal ligament. Anteriorly the prevertebral layer is separated from the pharynx and its covering buccopharyngeal fascia by a loose cellular interval which is termed the *retro-pharyngeal space.* Further from the median plane, the same loose areolar tissue connects the prevertebral layer to the pretracheal fascia, the carotid sheath and the fascia on the deep surface of the Sternomastoid muscle. It should be observed that all the anterior primary rami of the cervical nerves lie at first on the deep surface of the prevertebral layer, and certain of their important branches retain this position throughout their course in the neck, viz. the phrenic, the nerve to the Rhomboids (dorsalis scapulæ nerve) and the nerve to Serratus anterior (long thoracic).

The *pretracheal layer* of the cervical fascia is very thin and owes such importance as it possesses to its intimate relationship with the thyroid gland, for which it provides a fine fascial sheath. Above, it is attached to the arch of the cricoid cartilage, and, below, it is continued into the superior mediastinum as an investment for the inferior thyroid veins.

Applied Anatomy.—The deep cervical fascia is of considerable importance from a surgical point of view. The investing layer opposes the extension of abscesses towards the surface, and pus forming beneath it has a tendency to extend laterally. If the pus be contained in the anterior triangle, it may find its way into the mediastinum, in front of the pretracheal layer of fascia; but owing to the thinness of the fascia in this situation it more frequently finds its way to the surface and points above the sternum. Pus forming behind the prevertebral layer, in cases, for instance, of caries of the bodies of the cervical vertebræ, may extend towards the lateral part of the neck and point in the posterior triangle, or may perforate this layer of fascia and the buccopharyngeal fascia and point into the pharynx (retropharyngeal abscess).

In cases of cut throat, when the wound involves only the investing layer the injury is usually trivial, the special danger being injury to the external jugular vein. But where the second of the two layers is opened up, important structures may be injured, and serious results follow.

I. The Superficial and Lateral Cervical Muscles

Platysma. Trapezius. Sternocleidomastoideus.

The **Platysma** (fig. 574) is a broad sheet arising from the fascia covering the upper parts of the Pectoralis major and Deltoid; its fibres cross the clavicle, and proceed obliquely upwards and medially in the side of the neck. The anterior fibres interlace, below and behind the symphysis menti, with the fibres of the muscle of the opposite side; the posterior fibres cross the mandible, some being inserted into the bone below the oblique line, others into the skin and subcutaneous tissue of the lower part of the face, many of these fibres blending with the muscles about the angle and lower part of the mouth. Sometimes fibres can be traced to the Zygomaticus major or to the margin of the Orbicularis oculi. Under cover of the Platysma, the external jugular vein descends from the angle of the mandible to the middle of the clavicle.

Nerve-supply.—The Platysma is supplied by the cervical branch of the facial nerve.

Actions.—When the entire Platysma is in action it produces a wrinkling of the surface of the skin of the neck in an oblique direction, and tends to diminish the concavity between the jaw and the side of the neck. Its anterior portion, which is the thickest part of the muscle, may assist in depressing the mandible; it also serves to draw down the lower lip and angle of the mouth in the expression of horror or surprise.

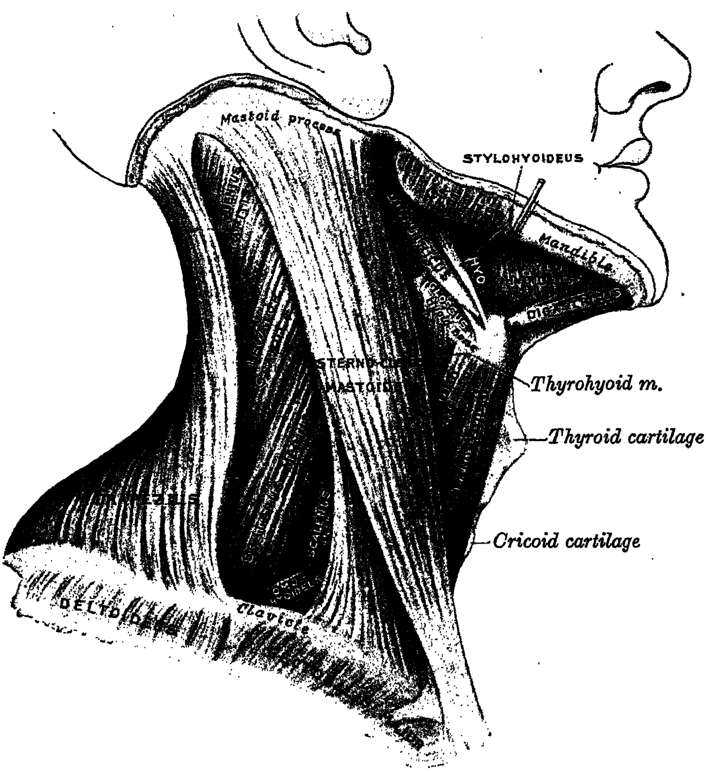
The **Trapezius** is described on p. 582.

The **Sternomastoid** (fig. 585) passes obliquely across the side of the neck. It is thick and narrow at its central part, but broader and thinner at each end. It arises by two heads. The *medial* or *sternal head* is a rounded tendinous fasciculus, which arises from the upper part of the anterior surface of the manubrium sterni, and is directed upwards, laterally, and backwards. The *lateral* or *clavicular head,* composed of fleshy and aponeurotic fibres, arises from the superior border and anterior surface of the medial one-third of the clavicle, and is directed almost vertically upwards. The two heads are separated from each other at their origins by a triangular interval, but, as they ascend, the clavicular head passes under cover of the sternal head and blends with its deep surface below the middle of the neck, forming a thick, rounded belly. The muscle is inserted by a strong tendon into the lateral surface of the mastoid process, from its apex to its superior border, and by a thin aponeurosis into the lateral half of the superior nuchal line of the occipital bone.

The clavicular head of the Sternomastoid may be as narrow as the sternal head, or may have a width of 7·5 cm.; when it is broad it is occasionally subdivided into several slips. More rarely, the adjoining margins of the Sternomastoid and Trapezius are in contact.

This muscle divides the quadrilateral area of the side of the neck into two triangles, an anterior and a posterior. The boundaries of the *anterior triangle* are, in front, the median line of the neck ; above, the base of the mandible, and a line continuing this from the angle of the mandible to the Sternomastoid ; behind, the anterior border of the Sternomastoid. The apex of the triangle is at the upper border of the sternum. The boundaries of the *posterior triangle* are, in front, the posterior border of the Sternomastoid ; below, the middle one-third of the clavicle ; behind, the anterior margin of the Trapezius. The apex corresponds with the meeting of the Sternomastoid and Trapezius on the occipital bone. The subdivisions and contents of these triangles are given on pp. 716 to 720.

FIG. 585.—The muscles of the neck. Right lateral aspect.



Relations.—*Superficial* to the muscle are the skin and Platysma ; it is separated from the Platysma by the external jugular vein, the great auricular and anterior cutaneous cervical nerves, and the investing layer of the deep cervical fascia. Near its insertion the muscle is overlapped by a small portion of the parotid gland. The *deep surface* of the muscle is related at its origin to the sternoclavicular joint ; it lies upon the Sternohyoid, Sternothyroid and the Omohyoid muscles, while the anterior jugular vein crosses deep to it but superficial to the infrahyoid muscles immediately above the clavicle. The carotid sheath and the subclavian artery are deep to these muscles. Between the Omohyoid and the posterior belly of the Digastric the anterior part of the Sternomastoid overlaps the common, internal and external carotid arteries, the internal jugular, common facial and lingual veins, the deep cervical lymph glands, and the vagus, descendens hypoglossi and descending cervical nerves. The sternomastoid branch of the superior thyroid artery crosses deep to the muscle at the upper border of the Omohyoid. The posterior part of the muscle is related deeply to the Splenius, Levator scapulæ and Scaleni, the cervical plexus, the upper part of the brachial plexus, the phrenic nerve, and the transverse cervical and suprascapular arteries. The occipital artery crosses deep to the muscle at, or under cover of, the lower border of the Digastric, where the accessory nerve, which pierces the muscle, runs downwards and laterally deep to it. At its insertion the muscle lies superficial to the mastoid process, and to the Splenius, Longissimus capitis, and the posterior belly of the Digastric.

Nerve-supply.—The Sternomastoid is supplied by the accessory nerve, which traverses it, and by branches from the anterior primary rami of the second and third cervical nerves.

Actions.—When one Sternomastoid acts, it draws the head towards the shoulder of the same side; it also rotates the head so as to carry the face towards the opposite side. Acting together from their sternoclavicular attachments the two muscles flex the head and the cervical part of the vertebral column; if the head be fixed, they assist in elevating the thorax in forced inspiration.

Applied Anatomy.—The deformity known as *wry-neck* is due to a contracted condition of the Sternomastoid. It may be temporary, as the result of direct irritation of the muscle or of the nerves supplying it. It may, however, be permanent, and is then most often due to injury to the muscle during birth, rupture of the fibres and subsequent cicatricial contraction taking place. In these cases, division of the muscle is often necessary to effect a cure.

There is also a condition coming on in adult life (spasmodic torticollis) which begins with tonic or clonic spasm of one Sternomastoid, soon followed by a spasm of the Trapezius, particularly its clavicular portion.

II. The Supra- and Infra-hyoid Muscles

The suprahyoid muscles are:

Digastricus.	Mylohyoideus.
Stylohyoideus.	Geniohyoideus.

The **Digastric** (fig. 585) consists of two fleshy bellies united by an intermediate rounded tendon. It lies below the body of the mandible, and extends, in a curved form, from the mastoid process to the chin. The *posterior belly*, longer than the anterior, arises from the mastoid notch of the temporal bone and passes downwards and forwards. The *anterior belly* arises from the digastric fossa on the base of the mandible close to the median plane, and passes downwards and backwards. The two bellies end in an intermediate tendon, which perforates the Stylohyoid muscle. It is held in connexion with the side of the body and the greater cornu of the hyoid bone by a fibrous loop, which is sometimes lined by a synovial sheath. An aponeurotic layer, sometimes named the *suprahyoid aponeurosis*, is given off from the tendon of the Digastric muscle, and is attached to the body and greater cornu of the hyoid bone.

Relations.—Its superficial surface is in relation with the Platysma, Sternomastoid, part of the Splenius, Longissimus capitis, mastoid process, Stylohyoid and the parotid gland. The *deep surface* of the anterior belly lies on the Mylohyoid; that of the posterior belly on the Superior oblique, Rectus capitis lateralis, the transverse process of the atlas vertebra, the accessory nerve, internal jugular vein, occipital artery, hypoglossal nerve, the internal and external carotid, the facial and lingual arteries and the Hyoglossus muscle (fig. 586).

Nerve-supply.—The anterior belly of the Digastric is supplied by the mylohyoid branch of the inferior dental (inferior alveolar) nerve; the posterior belly by the facial nerve.

Actions.—When the anterior belly of the Digastric takes its fixed point below, it depresses the front of the mandible. When both bellies are in action from above they elevate the hyoid bone.

The Digastric divides the upper part of the anterior triangle of the neck into three triangles: (1) the *digastric triangle*, bounded above by the base of the mandible and a line continuing this from the angle of the mandible to the Sternomastoid, below by the posterior belly of the Digastric and the Stylohyoid, in front by the anterior belly of the Digastric; (2) the *carotid triangle*, bounded above by the posterior belly of the Digastric and Stylohyoid, behind by the Sternomastoid, below by the Omohyoid; (3) the *submental triangle*, bounded on each side by the anterior belly of the Digastric, and inferiorly by the body of the hyoid bone.

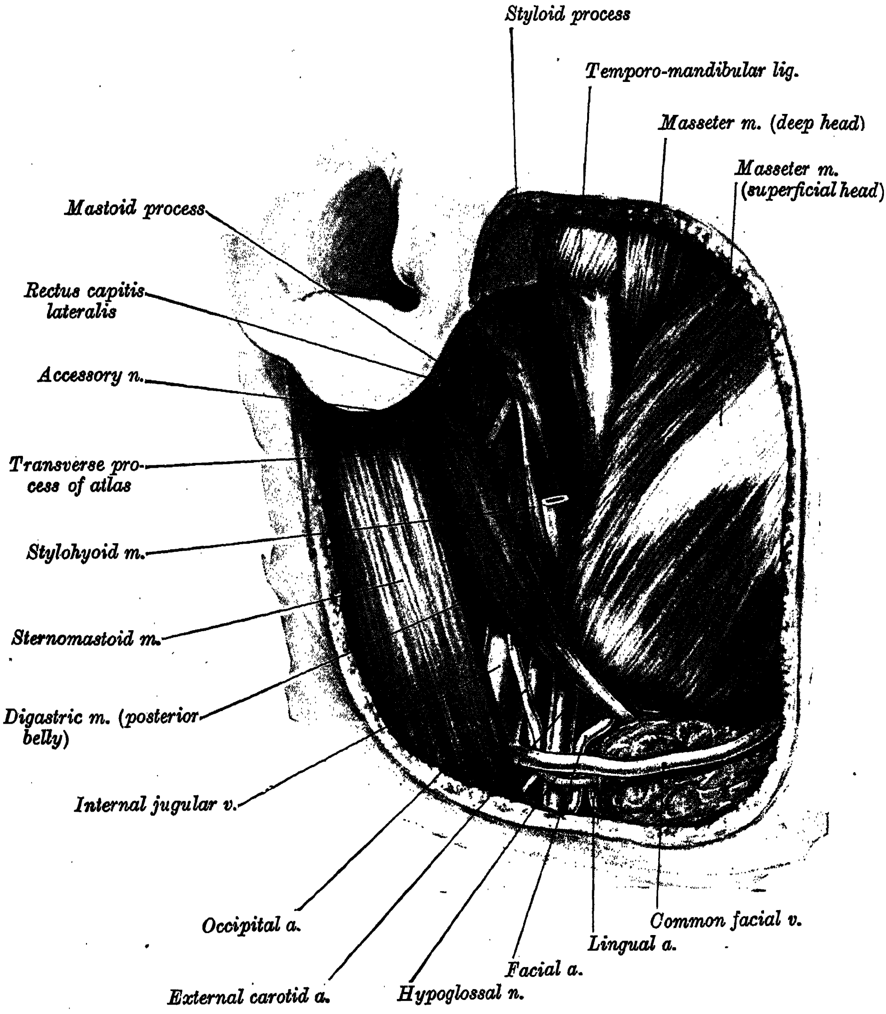
The **Stylohyoid** (figs. 586, 587) arises by a delicate little tendon from the posterior and lateral surfaces of the styloid process, near its base; and, passing

downwards and forwards, is inserted into the body of the hyoid bone, at its junction with the greater cornu, and just above the Omohyoid. It is perforated, near its insertion, by the tendon of the Digastric.

Nerve-supply.—The Stylohyoid is supplied by the facial nerve.

Action.—The Stylohyoid draws the hyoid bone upwards and backwards during the act of deglutition.

Fig. 586.—The relations of the posterior belly of the Digastric muscle of the right side.



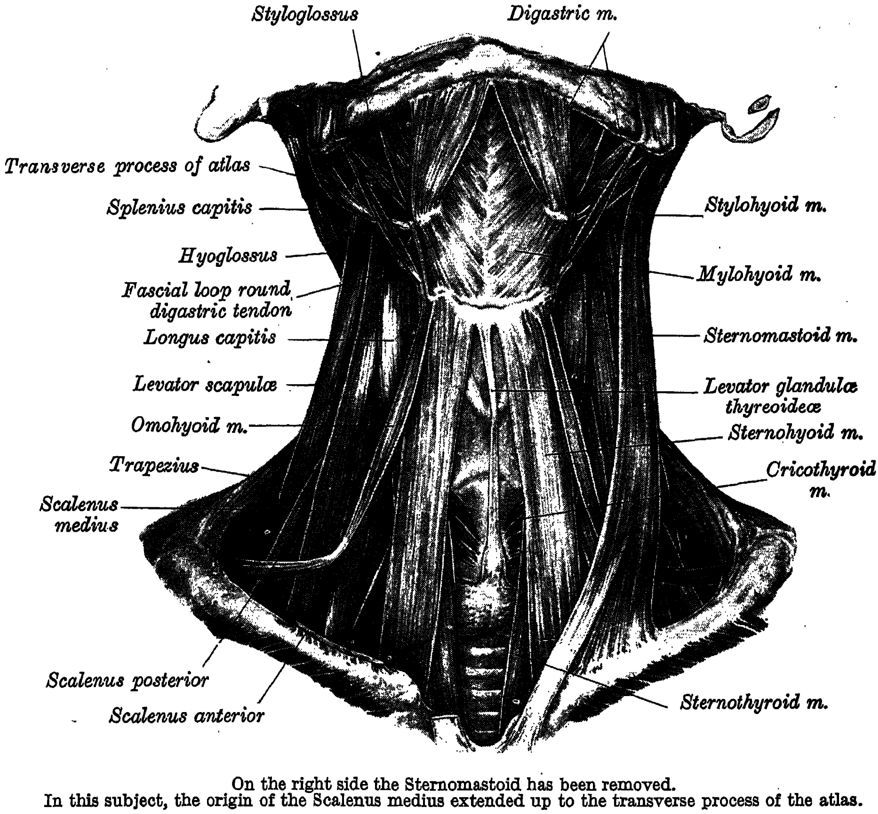
The parotid gland has been removed; the external carotid artery has been divided below its point of entry into the gland; and the facial nerve has been cut just below the stylomastoid foramen.

The *stylohyoid ligament.*—In connexion with the Stylohyoid muscle a ligamentous band, named the *stylohyoid ligament,* may be described. It is a fibrous cord, which is attached to the tip of the styloid process of the temporal bone and to the lesser cornu of the hyoid bone. It gives origin to the highest fibres of the Constrictor pharyngis medius and is intimately related to the lateral wall of the oral pharynx (fig. 1150). Below, it is covered by the Hyoglossus muscle. It frequently contains a little piece of cartilage in its centre, is often partially ossified, and in many animals forms a distinct bone, termed the *epihyal.* The stylohyoid ligament represents a portion of the skeletal element of the second visceral arch.

The **Mylohyoid** (figs. 585, 587) is situated immediately above the anterior belly of the Digastric, and forms, with its fellow of the opposite side, a muscular floor for the cavity of the mouth. It is a flat, triangular sheet which arises from the whole length of the mylohyoid line of the mandible. The posterior fibres pass medially and slightly downwards, to be inserted into the front of the body of the hyoid bone near its lower border. The middle and anterior fibres are inserted into a median fibrous raphe which stretches from the symphysis menti to the hyoid bone. This median raphe is sometimes wanting ; if so, the two muscles are continuous.

Relations.—Its *superficial* or *inferior surface* is in relation with the Platysma, the anterior belly of the Digastric, the suprahyoid aponeurosis, the superficial part of the submandibular (submaxillary) gland, the facial and submental vessels, and the mylohyoid vessels and nerve.

FIG. 587.—The muscles of the front of the neck.



On the right side the Sternomastoid has been removed.
In this subject, the origin of the Scalenus medius extended up to the transverse process of the atlas.

Its *deep* or *superior surface* is in relation with the Geniohyoid, part of the Hyoglossus, and the Styloglossus muscles, the hypoglossal and lingual nerves, the submandibular ganglion, the sublingual gland, the deep portion of the submandibular gland and the submandibular duct, the lingual and sublingual vessels, and the buccal mucous membrane.

Nerve-supply.—The Mylohyoid muscle is supplied by the mylohyoid branch of the inferior dental (inferior alveolar) nerve.

Actions.—Acting from below the Mylohyoid depresses the front of the mandible ; acting from above it raises the hyoid bone and the floor of the mouth.

The **Geniohyoid** (fig. 1146) is a narrow muscle, situated above the medial part of the Mylohyoid. It arises from the inferior genial tubercles on the back of the symphysis menti, and runs backwards and slightly downwards, to be inserted into the anterior surface of the body of the hyoid bone ; it is in contact with its fellow of the opposite side.

Nerve-supply.—The Geniohyoid muscle is supplied by the first cervical nerve through the hypoglossal nerve.

Actions.—When the Geniohyoid acts from the hyoid bone, it depresses the front of the mandible; when it acts from the mandible it raises and pulls forwards the hyoid bone.

The infrahyoid muscles are:

Sternohyoideus.	Thyreohyoideus.
Sternothyreoideus.	Omohyoideus.

The **Sternohyoid** (figs. 585, 587), a thin, narrow muscle, arises from the posterior surface of the medial end of the clavicle, the posterior sternoclavicular ligament, and the upper and posterior part of the manubrium sterni. Passing upwards and medially, it is inserted into the lower border of the body of the hyoid bone. It sometimes presents, near its origin, a transverse tendinous intersection. Below, the Sternohyoid is separated from its fellow by a considerable interval; but the two muscles come into contact with each other in the middle of their course, and are contiguous above.

Nerve-supply.—The Sternohyoid muscle is supplied by branches from the loop (ansa hypoglossi) between the ramus descendens hypoglossi and the nervus descendens cervicalis.

Action.—The Sternohyoid depresses the hyoid bone.

The **Sternothyroid** (figs. 585, 587) is shorter and wider than the Sternohyoid, and lies under cover of it. It arises from the posterior surface of the manubrium sterni below the origin of the Sternohyoid, and from the edge of the cartilage of the first rib, and sometimes that of the second; it is inserted into the oblique line on the lamina of the thyroid cartilage. At the lower part of the neck this muscle is in contact with its fellow, but it diverges as it ascends; it is occasionally traversed by a transverse or oblique tendinous intersection. It is closely applied to the anterolateral surface of the lobe of the thyroid gland.

Nerve-supply.—The Sternothyroid muscle is supplied by branches from the ansa hypoglossi.

Action.—The Sternothyroid draws the larynx downwards.

The **Thyrohyoid**, a small, quadrilateral muscle, may be looked upon as an upward continuation of the Sternothyroid. It arises from the oblique line on the lamina of the thyroid cartilage, and is inserted into the lower border of the greater cornu of the hyoid bone.

Nerve-supply.—The Thyrohyoid muscle is supplied by a branch from the hypoglossal nerve. Like the nerve to the Geniohyoid, this nerve is ultimately derived from the first cervical nerve.

Actions.—The Thyrohyoid depresses the hyoid bone, or raises the larynx.

The **Omohyoid** (figs. 585, 587) consists of two fleshy bellies united at an angle by an intermediate tendon. It arises from the upper border of the scapula near the suprascapular notch, and occasionally from the suprascapular (superior transverse) ligament, its extent of attachment to the scapula varying from a few millimetres to 2·5 cm. From this origin, the *inferior belly* forms a flat, narrow fasciculus, which inclines forwards and slightly upwards across the lower part of the neck, being bound to the clavicle by a fibrous expansion; it then passes behind the Sternomastoid and there ends in the intermediate tendon. The *superior belly* passes almost vertically upwards from this tendon, close to the lateral border of the Sternohyoid muscle, and is inserted into the lower border of the body of the hyoid bone, lateral to the insertion of the Sternohyoid. The intermediate tendon, which varies in length and form, usually lies on the internal jugular vein, opposite the arch of the cricoid cartilage. It is held in position by a process of the deep cervical fascia which ensheathes it and is attached below to the clavicle and the first rib; it is by this fascial process that the angular form of the muscle is maintained.

Nerve-supply.—The superior belly of the Omohyoid is supplied by the ramus descendens hypoglossi; the inferior belly by a branch from the ansa hypoglossi.

Actions.—The Omohyoid muscle depresses the hyoid bone and carries it backwards and laterally. The Omohyoids are concerned also in prolonged inspiratory efforts; by rendering tense the lower part of the deep cervical fascia they lessen the inward suction of the soft parts, which would otherwise compress the great vessels and the apices of the lungs.

The inferior belly of the Omohyoid divides the posterior triangle of the neck

into an upper or *occipital* and a lower or *subclavian* triangle, while its superior belly divides the anterior triangle into an upper or *carotid* and a lower or *muscular* triangle.

III. The Anterior Vertebral Muscles (fig. 588)

Longus cervicis.	Rectus capitis anterior.
Longus capitis.	Rectus capitis lateralis.

The **Longus cervicis** (Longus colli) is situated on the anterior surface of the vertebral column, between the atlas and the third thoracic vertebra. It is divisible into three portions, an inferior oblique, a superior oblique, and a vertical; its origin and insertion consist of tendinous slips. The *inferior oblique portion*, which is the smallest part of the muscle, arises from the front of the bodies of the first two or three thoracic vertebræ; it runs upwards and laterally, and is inserted into the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebræ. The *superior oblique portion* arises from the anterior tubercles of the transverse processes of the third, fourth and fifth cervical vertebræ; it is directed upwards and medially, and is inserted by a narrow tendon into the anterolateral surface of the tubercle on the anterior arch of the atlas. The *vertical portion* arises from the front of the bodies of the upper three thoracic and lower three cervical vertebræ, and is inserted into the front of the bodies of the second, third and fourth cervical vertebræ.

Nerve-supply.—The Longus cervicis is supplied by branches from the anterior primary rami of the second, third and fourth cervical nerves.

Actions.—The Longus cervicis bends the cervical portion of the vertebral column forwards; in addition, the oblique portions flex the column laterally and the inferior oblique portion rotates it to the opposite side.

The **Longus capitis**, broad and thick above, narrow below, arises by tendinous slips from the anterior tubercles of the transverse processes of the third, fourth, fifth and sixth cervical vertebræ, and is inserted into the inferior surface of the basilar part of the occipital bone.

Nerve-supply.—The Longus capitis is supplied by branches from the anterior primary rami of the first, second and third cervical nerves.

Action.—The Longus capitis flexes the head.

The **Rectus capitis anterior** is a short, flat muscle situated behind the upper part of the Longus capitis. It arises from the anterior surface of the lateral mass of the atlas, and from the root of its transverse process, and is inserted into the inferior surface of the basilar part of the occipital bone in front of the occipital condyle.

Nerve-supply.—The Rectus capitis anterior is supplied by branches from the loop between the anterior primary rami of the first and second cervical nerves.

Action.—The Rectus capitis anterior flexes the head.

The **Rectus capitis lateralis** is a short, flat muscle which arises from the upper surface of the transverse process of the atlas and is inserted into the under surface of the jugular process of the occipital bone. In view of its attachments and its relations to the anterior and posterior primary rami of the first cervical nerve, the rectus capitis lateralis is regarded as homologous with the posterior intertransverse muscles.

Nerve-supply.—The Rectus capitis lateralis is supplied by branches from the loop between the anterior primary rami of the first and second cervical nerves.

Action.—The Rectus capitis lateralis bends the head to the same side.

IV. The Lateral Vertebral Muscles (fig. 588)

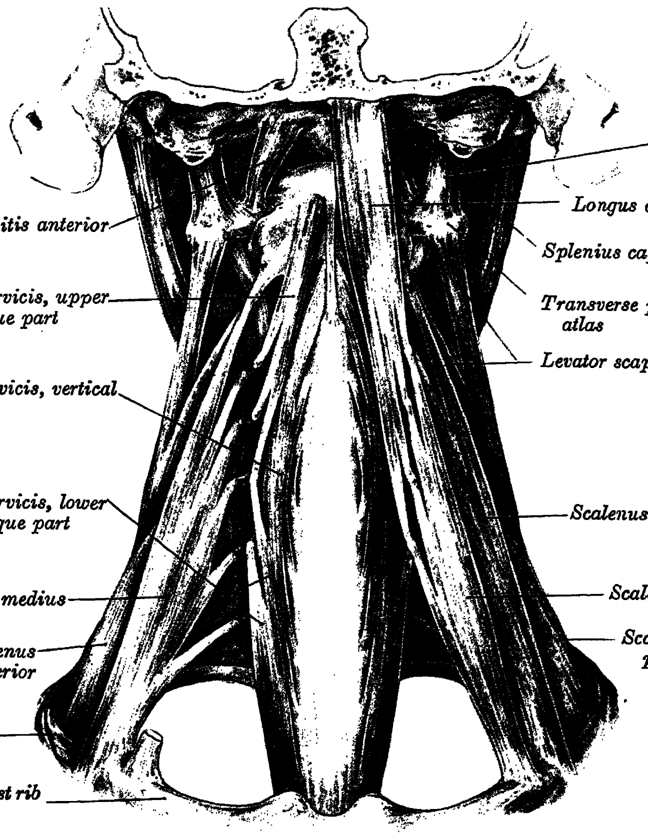
Scalenus anterior. Scalenus medius.
Scalenus posterior.

The **Scalenus anterior** lies deeply at the side of the neck, behind the Sternomastoid muscle. It arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descending,

almost vertically, is inserted by a narrow, flat tendon into the scalene tubercle on the inner border of the first rib, and into the ridge on the upper surface of the rib in front of the groove for the subclavian artery.

Relations.—*In front* of it are the clavicle, the Subclavius, Sternomastoid, and Omohyoid muscles, the lateral portion of the carotid sheath, the transverse cervical, suprascapular and ascending cervical arteries, the subclavian vein, the prevertebral fascia and the phrenic nerve. Its *posterior surface* is in relation with the pleura, and with the nerves forming the brachial plexus and the subclavian artery, which separate it from the Scalenus medius. Below, it is separated from the Longus cervicis by an angular interval (fig. 593), in which the vertebral artery, with its companion vein on its lateral side, ascends to reach the foramen

FIG. 588.—The anterior and lateral vertebral muscles.



On the right side the Scalenus anterior and the Longus capitis have been removed.

transversarium of the sixth cervical vertebra. The inferior thyroid artery crosses the interval from the lateral to the medial side near its apex. The sympathetic trunk and its inferior cervical ganglion are closely related to the medial side of this part of the vertebral artery. On the left side the thoracic duct crosses this interval at the level of the seventh cervical vertebra and usually comes into contact with the medial edge of the muscle. Above, it is separated from the Longus capitis by the ascending cervical branch of the inferior thyroid artery.

Nerve-supply.—The Scalenus anterior is supplied by branches from the anterior primary rami of the fourth, fifth, and sixth cervical nerves.

Actions.—Acting from below the Scalenus anterior bends the cervical portion of the vertebral column forwards and laterally and rotates it towards the opposite side. When the muscle acts from above it assists in elevating the first rib.

The **Scalenus medius**, the largest and longest of the Scaleni, arises from the front of the posterior tubercles of the transverse processes of the lower six

cervical vertebræ, and frequently extends upwards to the transverse process of the atlas (fig. 587); it is inserted into the upper surface of the first rib, between the tubercle of the rib and the groove for the subclavian artery.

Relations.—Its *anterolateral surface* is in relation with the Sternomastoid; it is crossed by the clavicle and the Omohyoid: *anteriorly*, it is separated from the Scalenus anterior by the subclavian artery and the cervical nerves. The Levator scapulæ and the Scalenus posterior are posterolateral to it. The upper two roots of the nerve to Serratus anterior (long thoracic nerve), and the nerve to the Rhomboids (dorsal scapular nerve) pierce the substance of the muscle and appear on its lateral surface.

Nerve-supply.—The Scalenus medius is supplied by branches from the anterior primary rami of the cervical nerves.

Actions.—The Scalenus medius, acting from below, bends the cervical part of the vertebral column to the same side; acting from above it helps to raise the thorax.

The **Scalenus posterior**, the smallest and deepest of the Scaleni, arises from the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, and is inserted by a thin tendon into the outer surface of the second rib, behind the tubercle for the Serratus anterior. It is occasionally blended with the Scalenus medius.

Nerve-supply.—The Scalenus posterior is supplied by branches from the anterior primary rami of the lower three cervical nerves.

Actions.—The Scalenus posterior bends the lower end of the cervical part of the vertebral column to the same side, when the second rib is fixed; if its upper attachment be fixed it helps to elevate the thorax.

THE FASCIÆ AND MUSCLES OF THE TRUNK

The muscles of the trunk may be arranged in six groups:

I. Deep muscles of the back.	IV. Muscles of the abdomen.
II. Suboccipital muscles.	V. Muscles of the pelvis.
III. Muscles of the thorax.	VI. Muscles of the perineum.

I. The Deep Muscles of the Back (fig. 590)

The deep or intrinsic muscles of the back consist of a complex group of muscles extending from the pelvis to the skull. They are:

Splenius capitis.	Multifidus.
Splenius cervicis.	Rotatores.
Sacrospinalis.	Interspinales.
Semispinalis.	Intertransversarii.

The **lumbar fascia** (lumbodorsal fascia) covers the deep muscles of the back of the trunk. Above, it passes in front of the Serratus posterior superior and is continuous with the investing fascial layer on the back of the neck.

In the thoracic region the lumbar fascia is a thin fibrous lamina covering the extensor muscles of the vertebral column and separating them from the muscles connecting the vertebral column to the upper extremity. It contains both longitudinal and transverse fibres, and is attached, *medially*, to the spines of the thoracic vertebræ; *laterally*, to the angles of the ribs.

In the lumbar region the lumbar fascia is in three layers, anterior, middle and posterior (fig. 589). The posterior layer is attached to the spines of the lumbar and sacral vertebræ and to the supraspinous ligament; the middle layer is attached, *medially*, to the tips of the transverse processes of the lumbar vertebræ, and to the intertransverse ligaments, *below*, to the iliac crest, and *above*, to the lower border of the twelfth rib and to the lumbocostal ligament (p. 447). The anterior layer covers the Quadratus lumborum and is attached *medially* to the anterior surfaces of the transverse processes of the lumbar vertebræ under cover of the lateral part of the Psoas major muscle. *Below*, it is attached to the iliolumbar ligament and the adjoining part of the iliac crest; *above*, it forms the lateral arcuate ligament (p. 555). The posterior and middle layers unite at the lateral margin of the Sacrospinalis, and at the lateral border of the Quadratus lumborum they are joined by the anterior layer to form the tendon of origin of the Transversus abdominis.

The **Splenius capitis** (fig. 613) arises from the lower half of the ligamentum nuchæ, from the spine of the seventh cervical vertebra, and from the spines of the upper three or four thoracic vertebræ. The fibres of the muscle are directed upwards and laterally and are inserted, under cover of the Sternomastoid muscle, into the mastoid process of the temporal bone, and into the rough surface on the occipital bone just below the lateral third of the superior nuchal line. It forms a part of the floor of the posterior triangle of the neck, above and behind the Levator scapulæ.

Nerve-supply.—The Splenius capitis is supplied by the lateral branches of the posterior primary rami of the middle cervical nerves.

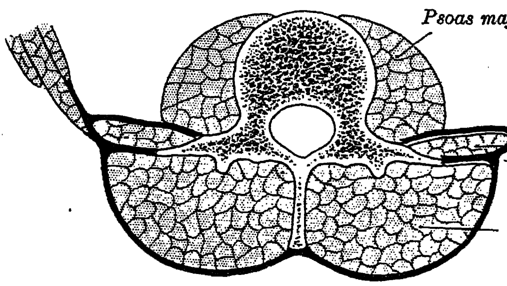
The **Splenius cervicis** (fig. 613) arises from the spines of the third to the sixth thoracic vertebræ ; it is inserted into the posterior tubercles of the transverse processes of the upper two or three cervical vertebræ immediately under cover of the origin of the Levator scapulæ.

Nerve-supply.—The Splenius cervicis is supplied by lateral branches of the posterior primary rami of the lower cervical nerves.

Actions.—The Splenii of the two sides, acting together, draw the head directly backwards ; acting separately, they draw the head to one side, and slightly rotate it, turning the face to the same side.

The **Sacrospinalis** (fig. 590), and its prolongations in the thoracic and cervical regions, lie in the groove on the side of the vertebral column, covered in the

FIG. 589.—A transverse section through the posterior abdominal wall, to show the disposition of the lumbar fascia. Diagrammatic.



lumbar and thoracic regions by the lumbar fascia. They form a large muscular and tendinous mass, which varies in size and structure at different parts of the vertebral column. In the sacral region it is narrow and pointed, and at its origin chiefly tendinous in structure. In the lumbar region it forms a thick fleshy mass which, on being followed upwards, divides into three columns ; these gradually diminish in size as they ascend to be inserted into the vertebræ and ribs.

The Sacrospinalis arises from the anterior surface of a broad and thick tendon, which is attached to the spinous tubercles of the sacrum (middle sacral crest), to the spines of the lumbar and the eleventh and twelfth thoracic vertebræ, to the supraspinous ligament, to the medial aspect of the dorsal segment (p. 368) of the iliac crest and to the transverse tubercles (lateral crest) of the sacrum, where it blends with the sacrotuberous and posterior sacro-iliac ligaments ; some of its fibres are continuous with the fibres of origin of the Gluteus maximus. The muscular fibres form a large fleshy mass, which splits in the upper lumbar region into three columns, viz. a lateral, the *Iliocostocervicalis*, an intermediate, the *Longissimus*, and a medial, the *Spinalis*. Each of these consists, from below upwards, of three parts, as follows :

Lateral Column.	*Intermediate Column.*	*Medial Column.*
Iliocostocervicalis	Longissimus.	Spinalis.
(*a*) Iliocostalis.	(*a*) L. thoracis.	(*a*) S. thoracis.
(*b*) Costalis.	(*b*) L. cervicis.	(*b*) S. cervicis.
(*c*) Costocervicalis.	(*c*) L. capitis.	(*c*) S. capitis.

The **Iliocostalis** (Iliocostalis lumborum) is inserted, by flattened tendons, into the inferior borders of the angles of the lower six or seven ribs.

The **Costalis** (Iliocostalis dorsi) arises from the upper borders of the angles of the lower

six ribs *medial* to the tendons of insertion of the Iliocostalis ; it is inserted into the upper borders of the angles of the upper six ribs and into the back of the transverse process of the seventh cervical vertebra.

The **Costocervicalis** (Iliocostalis cervicis) arises from the angles of the third, fourth, fifth and sixth ribs *medial* to the tendons of insertion of the costalis, and is inserted into the posterior tubercles of the transverse processes of the fourth, fifth and sixth cervical vertebræ.

Nerve-supply.—These three muscles are supplied by the posterior primary rami of the lower cervical, the thoracic and the upper lumbar nerves.

Actions.—These muscles are extensors of the vertebral column ; they also bend it to one side. The slips attached to the ribs act as depressors of the thorax.

The **Longissimus thoracis** is the intermediate and largest of the continuations of the Sacrospinalis. In the lumbar region, where it is as yet blended with the Iliocostalis, some of its fibres are attached to the whole length of the posterior surfaces of the transverse processes and the accessory processes of the lumbar vertebræ, and to the middle layer of the lumbar fascia. In the thoracic region it is inserted, by rounded tendons, into the tips of the transverse processes of all the thoracic vertebræ, and by fleshy processes into the lower nine or ten ribs between their tubercles and angles.

The **Longissimus cervicis**, situated medial to the Longissimus thoracis, arises by long thin tendons from the summits of the transverse processes of the upper four or five thoracic vertebræ, and is inserted by similar tendons into the posterior tubercles of the transverse processes of the cervical vertebræ from the second to the sixth inclusive.

The **Longissimus capitis** lies between the Longissimus cervicis and the Semispinalis capitis. It arises by tendons from the transverse processes of the upper four or five thoracic vertebræ, and the articular processes of the lower three or four cervical vertebræ, and is inserted into the posterior margin of the mastoid process, deep to the Splenius capitis and Sternomastoid. It is usually crossed by a tendinous intersection near its insertion.

Nerve-supply.—The Longissimi are supplied by the posterior primary rami of the lower cervical, the thoracic and the lumbar nerves.

Actions.—The Longissimi thoracis et cervicis bend the vertebral column backwards and laterally ; the Longissimus capitis extends the head, and turns the face towards the same side.

The **Spinalis thoracis**, the medial continuation of the Sacrospinalis, is scarcely separable as a distinct muscle. It is situated at the medial side of the Longissimus thoracis, and is intimately blended with it ; it arises by three or four tendons from the spines of the eleventh and twelfth thoracic, and first and second lumbar vertebræ ; these, uniting, form a small muscle which is inserted by separate tendons into the spines of the upper thoracic vertebræ, the number varying from four to eight. It is intimately united with the Semispinalis thoracis, which lies deep to it.

The **Spinalis cervicis** is an inconstant muscle, which arises from the lower part of the ligamentum nuchæ, the spine of the seventh cervical, and sometimes from the spines of the first and second thoracic vertebræ, and is inserted into the spine of the axis, and occasionally into the spines of the two vertebræ below it.

The **Spinalis capitis** is usually more or less blended with the Semispinalis capitis.

Nerve-supply.—The Spinales are supplied by the posterior primary rami of the lower cervical and thoracic nerves.

Actions.—The Spinales extend the vertebral column.

The **Semispinalis thoracis** consists of thin, fleshy fasciculi, interposed between tendons of considerable length. It arises by a series of tendons from the transverse processes of the thoracic vertebræ from the sixth to the tenth inclusive, and is inserted, by tendons, into the spines of the upper four thoracic and lower two cervical vertebræ.

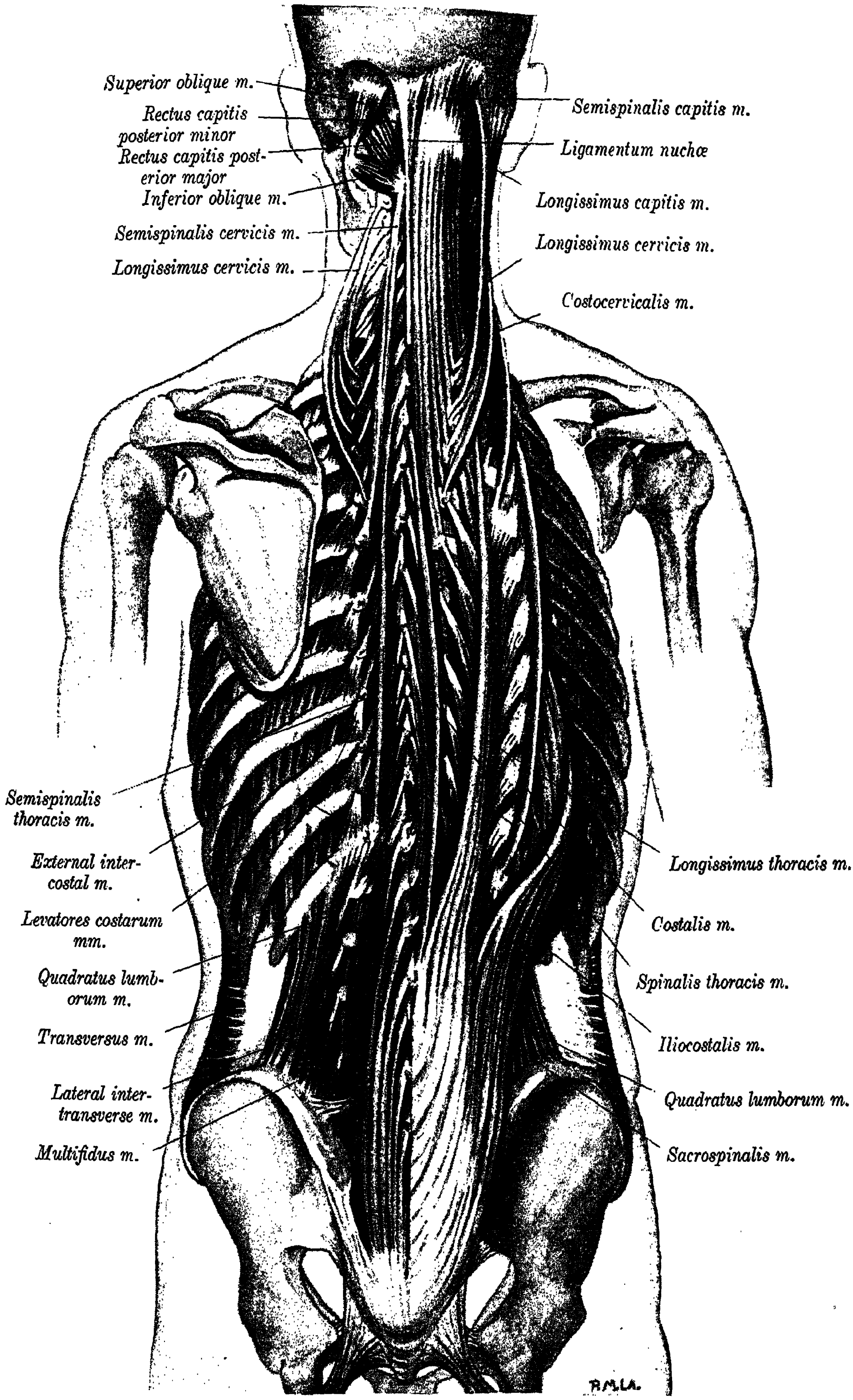
The **Semispinalis cervicis**, thicker than the preceding, arises by a series of tendinous and fleshy fibres from the transverse processes of the upper five or six thoracic vertebræ, and is inserted into the cervical spines, from the axis to the fifth inclusive. The fasciculus connected with the axis is the largest, and is chiefly muscular in structure.

The **Semispinalis capitis** is situated at the back part of the neck, under cover of the Splenius, and medial to the Longissimi cervicis et capitis. It arises by a series of tendons from the tips of the transverse processes of the upper six or seven thoracic and the seventh cervical vertebræ, and from the articular processes of the fourth, fifth, and sixth cervical vertebræ and, occasionally, from the spine of the seventh cervical or first thoracic vertebra. The tendons are succeeded by a broad muscle, which passes upwards and is inserted into the medial part of the area between the superior and inferior nuchal lines of the occipital bone. The medial part, usually more or less distinct from the rest of the muscle, is named the *Spinalis capitis* ; it is sometimes called the *Biventer cervicis*, since it is traversed by an imperfect tendinous intersection.

Nerve-supply.—The Semispinales are supplied by the posterior primary rami of the cervical and thoracic nerves.

Actions.—The Semispinales thoracis et cervicis extend the thoracic and cervical portions of the vertebral column, and rotate them towards the opposite side ; the Semispinalis capitis extends the head, and turns the face slightly towards the opposite side.

FIG. 590.—The deep muscles of the back.



N.B.—On the left side the Sacrospinalis muscle and its upward continuations (with the exception of the Longissimus cervicis m., which has been turned laterally) and the Semispinalis capitis muscle have been removed.

The **Multifidus** consists of a number of fleshy and tendinous fasciculi, which fill the groove at the side of the spines of the vertebræ, from the sacrum to the axis. In the sacral region, the fasciculi arise from the back of the sacrum as low as the fourth sacral foramen, from the aponeurosis of origin of the Sacrospinalis, from the medial surface of the posterior superior iliac spine and from the posterior sacro-iliac ligaments; in the lumbar region, from all the mamillary processes; in the thoracic region, from all the transverse processes; and in the cervical region, from the articular processes of the lower four vertebræ. Each fasciculus passes obliquely upwards and medially, and is inserted into the whole length of the spine of one of the vertebræ above. The fasciculi vary in length; the most superficial pass from one vertebra to the third or fourth above; those next in depth run from one vertebra to the second or third above; while the deepest connect contiguous vertebræ.

Nerve-supply.—The Multifidus is supplied by the posterior primary rami of the spinal nerves.

Actions.—The fasciculi of the Multifidus bend the segments of the vertebral column backwards and laterally, and rotate them towards the opposite side.

The **Rotatores** lie deep to the Multifidus and are found only in the thoracic region; they are eleven in number on each side, and are small and somewhat quadrilateral in form. Each arises from the upper and posterior part of the transverse process of one vertebra, and is inserted into the lower border and lateral surface of the lamina of the vertebra next above, the fibres extending as far as the root of the spine. The first is found between the first and second thoracic vertebræ; the last, between the eleventh and twelfth. Sometimes the number of these muscles is diminished by the absence of one or more from the upper or lower end of the series.

Nerve-supply.—The Rotatores are supplied by the posterior primary rami of the spinal nerves.

Actions.—The Rotatores mainly rotate the individual vertebræ towards the opposite side.

The **Interspinales** are short muscular fasciculi, placed in pairs between the spines of contiguous vertebræ, one on each side of the interspinous ligament. In the *cervical region* they are most distinct, and consist of six pairs; the first is situated between the axis and third vertebra, and the last between the seventh cervical and the first thoracic vertebræ. They are small narrow bundles, attached, above and below, to the apices of the spines. In the *thoracic region* they are found between the first and second vertebræ, and sometimes between the second and third, and the eleventh and twelfth vertebræ. In the *lumbar region* there are four pairs in the intervals between the five lumbar vertebræ. A pair is occasionally found between the last thoracic and first lumbar vertebræ, and another between the fifth lumbar vertebra and the sacrum.

Nerve-supply.—The Interspinales are supplied by the posterior primary rami of the spinal nerves.

Actions.—The Interspinales extend those segments of the vertebral column to which they are attached.

The **Extensor coccygis** is a slender muscular fasciculus, which is not always present; it extends over the lower part of the posterior surface of the sacrum and coccyx. It arises by tendinous fibres from the last segment of the sacrum, or first piece of the coccyx, and passes downwards to be inserted into the lower part of the coccyx. It is a rudiment of the Levator caudæ muscle of the lower animals.

The **Intertransversarii** are small muscles placed between the transverse processes of the vertebræ. They are best developed in the *cervical region* where they consist of anterior and posterior slips, which are separated by the anterior primary rami of the spinal nerves. The *posterior intertransverse muscles* are subdivisible into medial and lateral slips, which are separate morphological entities. The *anterior intertransverse muscles* and the lateral parts of the posterior muscles connect the costal processes of contiguous vertebræ, and the medial parts of the posterior muscles connect the true transverse processes. There are seven pairs of these muscles, the highest between the atlas and axis, and the lowest between the seventh cervical vertebra and the first thoracic, but the anterior muscle between the atlas and axis is often absent. In the *thoracic region* they consist of single muscles, which are present between the transverse processes of the three lower thoracic vertebræ only and between the transverse processes of the last thoracic vertebra and the first lumbar. In the *lumbar region* they again consist of two sets of muscles, one named the *Intertransversarii mediales*, connecting the accessory process of one vertebra with the mamillary process of the next, and the other named the *Intertransversarii laterales*, which are really divisible into ventral and dorsal parts.* The ventral parts connect the transverse processes (costal elements) of the lumbar vertebræ, and each dorsal part connects the accessory process to the transverse process of the succeeding vertebra.

* J. D. Lickley, *Journal of Anatomy and Physiology*, vol. xxxix., 1905, and A. J. E. Cave, *Journal of Anatomy*, vol. lxxi., 1937. According to the latter, the Intertransversarii mediales are homologous with the thoracic intertransverse muscles and with the medial slips of the posterior muscles in the cervical region: the ventral parts of the Intertransversarii laterales are homologous with both the lateral parts of the posterior muscles and the anterior muscles in the cervical region: and the dorsal parts of the Intertransversarii laterales are homologous with the levatores costarum.

Nerve-supply.—The Intertransversarii mediales, the thoracic Intertransversarii and the medial parts of the posterior intertransverse muscles in the cervical region are supplied by the posterior primary rami of the spinal nerves; the others are supplied by the anterior primary rami.

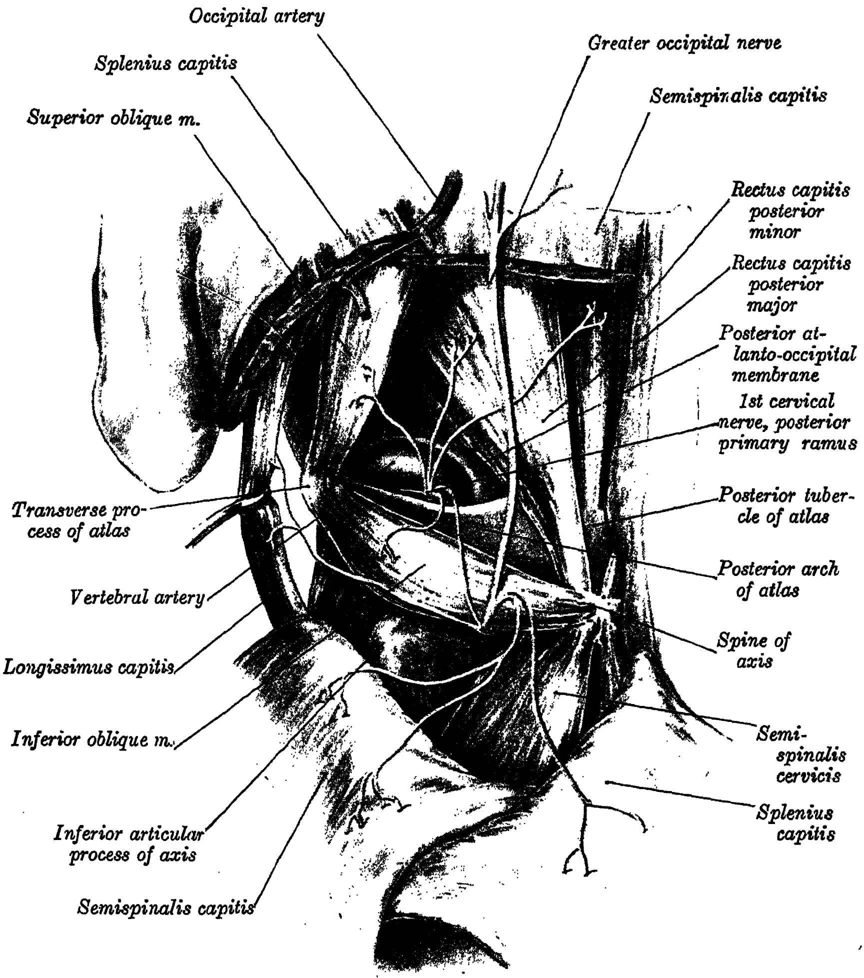
Actions.—The intertransverse muscles act as lateral flexors of those segments of the vertebral column to which they are attached.

II. The Suboccipital Muscles (fig. 591)

Rectus capitis posterior major.	Obliquus capitis inferior.
Rectus capitis posterior minor.	Obliquus capitis superior.

The **Rectus capitis posterior major** arises by a pointed tendon from the spine of the axis, and, becoming broader as it ascends, is inserted into the lateral

Fig. 591.—The left suboccipital triangle and muscles.



part of the inferior nuchal line of the occipital bone, and into the bone immediately below the line. As the muscles of the two sides pass upwards and laterally, they leave between them a triangular space, in which parts of the Recti capitis posteriores minores are seen.

Actions.—The Rectus capitis posterior major extends the head, and turns the face towards the same side.

The **Rectus capitis posterior minor** arises by a narrow pointed tendon from the tubercle on the posterior arch of the atlas, and, widening as it ascends, is

inserted into the medial part of the inferior nuchal line of the occipital bone and also into the bone between that line and the foramen magnum.

Action.—The Rectus capitis posterior minor extends the head.

The **Obliquus capitis inferior**, the larger of the two Oblique muscles, arises from the lateral surface of the spine of the axis, and passes laterally and slightly upwards, to be inserted into the lower and back part of the transverse process of the atlas.

Action.—The Obliquus capitis inferior turns the face towards the same side. *Owing to the length of the transverse process of the atlas the muscle is enabled to act to good mechanical advantage.*

The **Obliquus capitis superior**, narrow below, wide and expanded above, arises by tendinous fibres from the upper surface of the transverse process of the atlas. It passes upwards and backwards, and is inserted into the occipital bone, between the superior and inferior nuchal lines, lateral to the Semispinalis capitis and overlapping the insertion of the Rectus capitis posterior major.

Actions.—The Obliquus capitis superior bends the head backwards and to the same side.

Nerve-supply.—All the suboccipital muscles are supplied by the posterior primary ramus of C. 1.

The suboccipital triangle.—This triangle is bounded, above and medially, by the Rectus capitis posterior major; above and laterally, by the Obliquus capitis superior; below and laterally, by the Obliquus capitis inferior. Medially, the roof is formed by a layer of dense fibrofatty tissue, situated deep to the Semispinalis capitis, and, laterally, by the Longissimus capitis and sometimes by the Splenius capitis, which covers the Obliquus capitis superior. The floor of the triangle is formed by the posterior atlanto-occipital membrane and the posterior arch of the atlas; the vertebral artery and the posterior primary ramus of the first cervical nerve (fig. 591) lie in the groove on the upper surface of the posterior arch of the atlas.

III. The Muscles of the Thorax.

Intercostales externi.
Intercostales interni.
Transversus thoracis.
  Sternocostalis.
  Intercostales intimi.
  Subcostales.
Levatores costarum.
Serratus posterior superior.
Serratus posterior inferior.
Diaphragm.

The **Intercostales** externi et interni (fig. 615) are two thin layers of muscular and tendinous fibres occupying each of the intercostal spaces. They are named *external* and *internal* from their surface relations—the external being superficial to the internal.

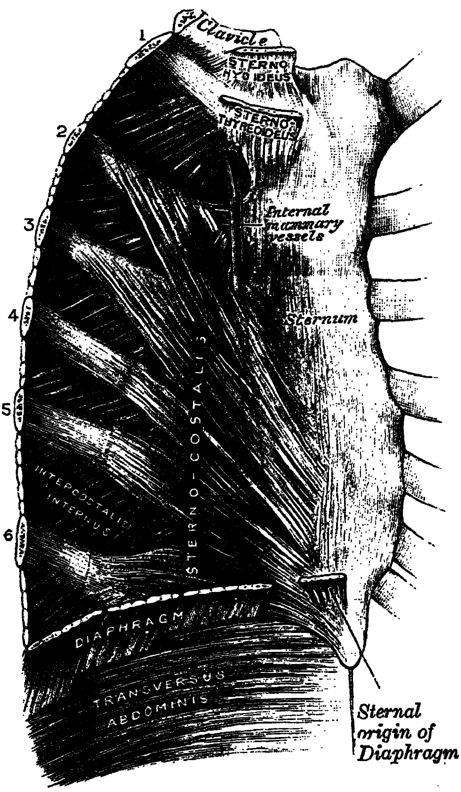
The **Intercostales externi** are eleven in number on each side. Their attachments extend from the tubercles of the ribs behind, where they are intimately related to the posterior fibres of the superior costotransverse ligaments, to near the cartilages of the ribs in front, where each is replaced by an aponeurotic layer named the *anterior intercostal membrane*, which is continued forwards to the sternum. Each muscle arises from the lower border of one rib, and is inserted into the upper border of the rib below. In the lower two spaces they extend to the ends of the rib-cartilages, and in the upper two or three spaces they do not quite reach the ends of the ribs. They are thicker than the Internal intercostals, and their fibres are directed obliquely downwards and laterally on the back of the thorax, and downwards, forwards, and medially on the front.

The **Intercostales interni** are also eleven in number on each side. Their attachments commence anteriorly at the sternum, in the interspaces between the cartilages of the true ribs, and at the anterior extremities of the cartilages of the false ribs, and extend backwards as far as the angles of the ribs, where each is replaced by an aponeurotic layer named the *posterior intercostal membrane*, which is continuous with the anterior fibres of the superior costotransverse ligament. Each muscle arises from the floor of the costal groove and the corresponding costal cartilage, and is inserted into the upper border of the rib below. Their fibres are also directed obliquely, but at right angles to those of the External intercostal muscles.

Actions.—The actions of the External and Internal intercostal muscles are very difficult to determine. It is generally believed that both groups act as elevators of the ribs, although some investigators have attributed the opposite action to the Internal intercostals. In addition, they form strong elastic supports, which prevent the intercostal spaces being drawn in or bulged out during respiration. The anterior portions of the Internal intercostals probably have an additional function in keeping the sternocostal and interchondral joint-surfaces in apposition, the posterior portions of the External intercostals performing a similar function for the costovertebral joints.

The **Transversus thoracis** is a thin plane of muscular and tendinous fibres situated upon the inner surface of the chest wall. It forms an incomplete investment and is divisible into three parts, viz.: the Subcostales, the Intercostales intimi and the Sternocostalis.

Fig. 592.—The left Sternocostalis. Posterior surface.



The **Subcostales** consist of muscular and aponeurotic fasciculi, and are usually well developed only in the lower part of the thorax; each arises from the inner surface of one rib near its angle, and is inserted into the inner surface of the second or third rib below. Their fibres run in the same direction as those of the Internal intercostals. They intervene between the intercostal vessels and nerves and the pleura.

Actions.—The Subcostals depress the ribs.

The **Intercostales intimi** * are placed on the deep surfaces of the Internal intercostals and their fibres pass in the same direction. Each is attached to the inner surfaces of two adjoining ribs. Poorly developed, sometimes absent, in the upper intercostal spaces, the Intercostales intimi become gradually more extensive from above downwards. Below each covers the middle two-fourths of the intercostal space, and its posterior border is edge to edge with the lateral border of the corresponding Subcostalis muscle. Like the Subcostales the Intercostales intimi separate the intercostal vessels and nerves from the pleura (fig. 593).

Actions.—The Intercostales intimi act in the same way as the Internal intercostals.

The **Sternocostalis** (Transversus thoracis) is situated upon the inner surface of the front wall of the chest (fig. 592). It arises from the lower third of the posterior surface of the body of the sternum, from the posterior surface of the xiphoid process, and from the posterior surfaces of the costal cartilages of the lower three or four true ribs near their sternal ends. Its fibres diverge as they pass upwards and laterally, to be inserted by slips into the lower borders and inner surfaces of the costal cartilages of the second, third, fourth, fifth, and sixth ribs. The lowest fibres of this muscle are horizontal, and are edge to edge with the highest fibres of the Transversus abdominis; the intermediate fibres are oblique, while the highest are almost vertical. This muscle varies in its attach-

* These muscles were originally called Intracostales, and they are regarded by some anatomists merely as parts of the Internal intercostals. For a full description consult the following: T. Walmsley, *Journal of Anatomy*, vol. l., and F. Davies, R. J. Gladstone and E. P. Stibbe, *Journal of Anatomy*, vol. lxvi.

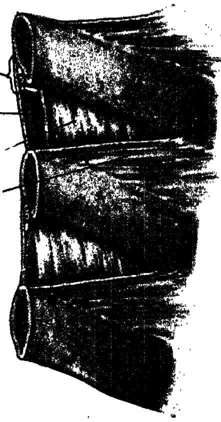
ments not only in different subjects but on opposite sides of the same subject. Like the other parts of the Transversus thoracis the Sternocostalis separates the intercostal nerves from the pleura.

Actions.—The Sternocostalis draws down the costal cartilages to which it is attached.

Nerve-supply.—All these muscles are supplied by the corresponding intercostal nerves.

The Levatores costarum (fig. 590), twelve in number on each side, are strong bundles which arise from the ends of the transverse processes of the seventh cervical and upper eleven thoracic vertebræ; they pass obliquely downwards and laterally, parallel with the posterior borders of the External intercostals, and each is inserted into the upper edge and outer surface of the rib immediately below the vertebra from which it takes origin, between the tubercle and the angle (Levatores costarum breves). Each of the four lower muscles divides into two fasciculi, one of which is inserted as above described; the other passes down to the second rib below its origin (Levatores costarum longi).

Fig. 593.—A dissection of a part of the thoracic wall, showing the position of the intercostal vessels and nerves relative to the intercostal muscles.



In both the spaces shown a part of the Intercostalis externus has been removed; in addition, in the upper space, a small strip of the Intercostalis internus has been reflected in order to expose the intercostal nerve lying on the surface of the Intercostalis intimus.

Nerve-supply.—The Levatores costarum are supplied by the intercostal nerves.

Actions.—The Levatores costarum being inserted near the fulcra of the ribs can have little or no elevating action on the ribs, but they may rotate the necks of the ribs in a forward direction; they are said to act as rotators and lateral flexors of the vertebral column.

The Serratus posterior superior is a thin, quadrilateral muscle, situated at the upper and posterior part of the thorax. It arises by a thin aponeurosis from the lower part of the ligamentum nuchæ, from the spines of the seventh cervical and upper two or three thoracic vertebræ and from the supraspinous ligament. Inclining downwards and laterally it is inserted, by four fleshy digitations, into the upper borders and outer surfaces of the second, third, fourth, and fifth ribs, a little beyond their angles. It lies superficial to the upward continuation of the lumbar fascia and is hidden by the Rhomboid muscles.

Nerve-supply.—The Serratus posterior superior is supplied by the second, third, fourth and fifth intercostal nerves.

Actions.—The Serratus posterior superior elevates the ribs to which it is attached.

The Serratus posterior inferior (fig. 613) is situated at the junction of the thoracic and lumbar regions: it is of an irregularly quadrilateral form, broader than the preceding muscle, and separated from it by a wide interval. It arises by a thin aponeurosis from the spines of the lower two thoracic and upper two or three lumbar vertebræ and from the supraspinous ligament; this aponeurosis is intimately blended with the lumbar fascia. Passing obliquely upwards and laterally, it becomes fleshy, and is inserted by four digitations into the inferior borders and outer surfaces of the lower four ribs, a little beyond their angles.

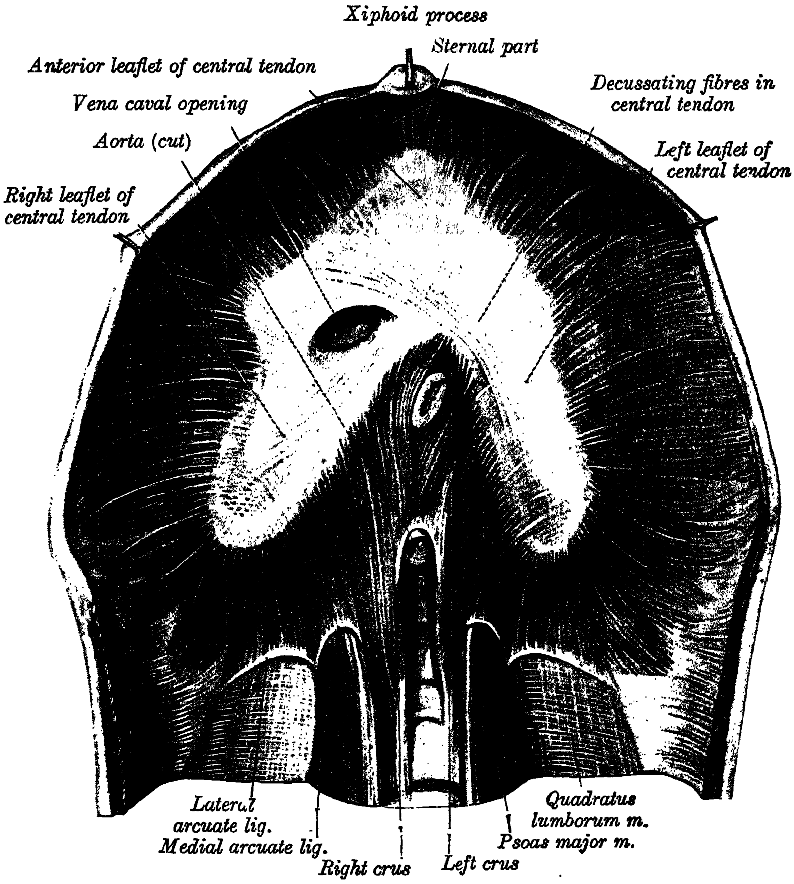
Nerve-supply.—The Serratus posterior inferior is supplied by the anterior primary rami of the ninth, tenth, eleventh and twelfth thoracic nerves.

Actions.—The Serratus posterior inferior draws the lower ribs downwards and backwards and thus elongates the thorax; it also fixes the lower ribs, thus assisting the inspiratory action of the Diaphragm and resisting the tendency of the latter to draw the lower ribs upwards and forwards.

The **Diaphragm** (fig. 594) is a dome-shaped, musculofibrous septum which separates the thoracic from the abdominal cavity, its convex upper surface forming the floor of the former, and its concave under surface the roof of the latter. Its peripheral part consists of muscular fibres which take origin from the circumference of the thoracic outlet and converge to be inserted into a central tendon.

The muscular fibres may be grouped according to their origins into three parts—sternal, costal, and vertebral. The *sternal part* arises by two fleshy slips from the back of the ziphoid process; the *costal part* from the inner surfaces of the cartilages and adjacent portions of the lower six ribs on each side, interdigitating with the Transversus abdominis (fig. 592); and the *vertebral part*

FIG. 594.—The Diaphragm. Abdominal surface.



from aponeurotic arches, named the arcuate ligaments (lumbocostal arches), and from the lumbar vertebræ by two pillars or *crura*. There are two arcuate ligaments, a lateral and a medial, on each side, and, in addition, a *median arcuate ligament* connects the two crura across the median plane.

The *lateral arcuate ligament* (lateral lumbocostal arch), which is a thickened band in the fascia covering the Quadratus lumborum, arches across the upper part of that muscle, and is attached, medially, to the front of the transverse process of the first lumbar vertebra, and, laterally, to the lower margin of the twelfth rib.

The *medial arcuate ligament* (medial lumbocostal arch) is a tendinous arch in the fascia covering the upper part of the Psoas major; medially, it is continuous with the lateral tendinous margin of the corresponding crus, and is attached to the side of the body of the first or second lumbar vertebra; laterally, it is fixed to the front of the transverse process of the first lumbar vertebra.

The crura.—At their origins the crura are tendinous in structure, and blend with the anterior longitudinal ligament of the vertebral column. The *right crus*, larger and longer than the left, arises from the anterior surfaces of the bodies and

intervertebral discs of the upper three lumbar vertebræ, while the *left crus* arises from the corresponding parts of the upper two only. The medial tendinous margins of the crura meet in the median plane to form an arch across the front of the aorta, which is termed the *median arcuate ligament*; it is often poorly defined.

From this series of origins the fibres of the Diaphragm converge to be inserted into the central tendon. The fibres arising from the xiphoid process are very short, and occasionally aponeurotic; those from the medial and lateral arcuate ligaments, and more especially those from the ribs and their cartilages, are longer, and describe marked curves as they ascend and converge to their insertion. The fibres arising from the crura diverge as they ascend, the most lateral being directed upwards and laterally to the central tendon. The medial fibres of the right crus ascend on the left side of the œsophageal opening, and occasionally a fleshy fasciculus from the medial side of the left crus crosses the aorta and runs obliquely through the fibres of the right crus towards the venacaval opening, but this fasciculus "is never continued upwards to help to bound the œsophageal passage on the right side" (Low *).

The *central tendon* of the Diaphragm is a thin but strong aponeurosis of closely interwoven fibres situated near the centre of the vault formed by the muscle, but somewhat closer to the front than to the back of the thorax, so that the posterior muscular fibres are the longer. It is placed immediately below the pericardium, with which it is partially blended. It is shaped somewhat like a trefoil leaf, and consists of three divisions or leaflets separated from one another by slight indentations. The middle leaflet has the form of an equilateral triangle, the apex of which is directed towards the xiphoid process of the sternum. The right and left leaflets are rather tongue-shaped and curve laterally and backwards, the left being a little narrower than the right. The central area of the tendon is occupied by four well-marked diagonal bands radiating from a thick central point like the bars of a St. Andrew's cross, and then expanding in a fan-shaped manner; the central point of decussation appears as a thick node of compressed tendinous strands situated in front of the œsophageal aperture, and to the left of the venacaval opening.†

Openings in the Diaphragm (fig. 594).—The Diaphragm is pierced by apertures for the passage of structures between the thorax and abdomen. Three large openings—the aortic, the œsophageal, and the venacaval—and a number of small ones are present.

The *aortic opening* is the lowest and most posterior of the large apertures; it lies at the level of the lower border of the twelfth thoracic vertebra, slightly to the left of the median plane. Strictly speaking, it is an osseo-aponeurotic opening between the vertebral column and the Diaphragm, and therefore behind the latter; occasionally some tendinous fibres from the medial parts of the crura pass behind the aorta, and convert the opening into a fibrous ring. The aortic opening transmits the aorta and the thoracic duct.‡

The *œsophageal opening* is situated in the muscular part of the Diaphragm at the level of the tenth thoracic vertebra; it is elliptical in shape, and is "formed by the splitting of the medial fibres of the right crus" (Low). It is placed above, in front, and a little to the left of the aortic opening, and transmits the œsophagus, the vagus nerves, and the œsophageal branches of the left gastric artery.

The *venacaval opening*, the highest of the three large openings, is situated about the level of the disc between the eighth and ninth thoracic vertebræ. It is quadrilateral in form, and is placed at the junction of the right leaflet with the central area, so that its margins are tendinous. It transmits the inferior vena cava, the wall of which is adherent to the margin of the opening, and some branches of the right phrenic nerve.

There are two *lesser apertures* in each crus; of these one transmits the greater and the other the lesser splanchnic nerve. The ganglionated trunks of the sympathetic usually enter the abdominal cavity behind the Diaphragm, deep to the medial arcuate ligaments. Openings for minute veins are frequently seen in the central tendon.

* Alex. Low, *Journal of Anatomy and Physiology*, vol. xlii.

† D. M. Blair, *Journal of Anatomy*, vol. lvii. p. 203.

‡ It is stated frequently that the azygos vein passes through the aortic opening, but this description is not always strictly accurate (see p. 827).

Blair (*loc. cit.*) describes one of varying size, but of constant position, and present in ten out of twelve specimens he examined. It occurs in the angle between the left pair of bands as they diverge from the central point of decussation, and he suggests that the vein it transmits may represent the suprahepatic part of the left vitelline vein.

On each side there are two small areas where the muscular fibres of the Diaphragm are deficient and are replaced by areolar tissue. One between the sternal and costal parts transmits the superior epigastric branch of the internal mammary artery and some lymph vessels from the abdominal wall and convex surface of the liver. The other, between the fibres springing from the medial and lateral arcuate ligaments, is less constant; when this interval exists, the upper and back part of the kidney is separated from the pleura by areolar tissue only.

Relations.—The upper surface of the Diaphragm is in relation with three serous membranes, viz. on each side with the pleura, which separates it from the base of the corresponding lung, and on the middle leaflet of the central tendon with the pericardium, which intervenes between it and the heart. The central portion lies on a slightly lower level than the summits of the lateral portions. The greater part of the under surface is covered by the peritoneum. The right side is accurately moulded over the convex surface of the right lobe of the liver, the right kidney, and right suprarenal gland; the left over the left lobe of the liver, the fundus of the stomach, the spleen, the left kidney, and the left suprarenal gland.

Nerve-supply.—The Diaphragm is supplied by the phrenic nerve and the lower six or seven intercostal nerves, the latter being distributed to the peripheral part of the muscle.

Actions.—The Diaphragm is the principal muscle of inspiration, and presents the form of a dome concave towards the abdomen. The central part of the dome is tendinous, and the pericardium is attached to its upper surface; the circumferential part is muscular. During inspiration the lowest ribs are fixed, and from these and the crura the muscular fibres contract and draw downwards and forwards the central tendon with the attached pericardium. In this movement the curvature of the Diaphragm is scarcely altered, the dome moving downwards nearly parallel to its original position and pushing before it the abdominal viscera. The descent of the abdominal viscera is permitted by the extensibility of the abdominal wall, but the limit of this is soon reached. The central tendon, applied to the abdominal viscera, then becomes a fixed point for the action of the Diaphragm, the effect of which is to elevate the lower ribs and through them to push forwards the body of the sternum and the upper ribs. The right cupola of the Diaphragm, lying on the liver, has a greater resistance to overcome than the left, which lies over the stomach, but to compensate for this the right crus and the fibres of the right side generally are stronger than those of the left.

In all expulsive acts the Diaphragm is called into action to give additional power to each effort. Thus, before sneezing, coughing, laughing, crying, or vomiting, and previous to the expulsion of urine, or fæces, or of the fœtus from the uterus, a deep inspiration takes place.

According to Whillis the fibres of the right crus exert a sphincteric action on the lower end of the œsophagus in man. The act of expiration, which immediately succeeds the act of swallowing, relaxes these fibres and allows the contents of the œsophagus to pass into the stomach.*

The height of the Diaphragm is constantly varying during respiration; it also varies with the degree of distension of the stomach and intestines and with the size of the liver. After a forced expiration the right cupola is on a level in front with the fourth costal cartilage, at the side with the fifth, sixth, and seventh ribs, and behind with the eighth rib; the left cupola is a little lower than the right. Halls Dally † states that the absolute range of movement between deep inspiration and deep expiration averages in the male and female 30 mm. on the right side and 28 mm. on the left; in quiet respiration the average movement is 12·5 mm. on the right side and 12 mm. on the left.

Skiagraphy shows that the height of the Diaphragm in the thorax varies considerably with the position of the body. It stands highest when the body is horizontal and the patient on his back, and in this position it performs the largest respiratory excursions

* J. Whillis, *Journal of Anatomy*, vol. lxi. 1931.

† *Journal of Anatomy and Physiology*, vol. xliii.

with normal breathing. When the body is erect the dome of the Diaphragm falls, and its respiratory movements become smaller. The dome falls still lower when the sitting posture is assumed, and in this position its respiratory excursions are smallest. When the body is horizontal and the patient on his side, the two halves of the Diaphragm do not behave alike. The uppermost half sinks to a level lower even than when the patient sits, and moves little with respiration; the lower half rises higher in the thorax than it does when the patient is supine, and its respiratory excursions are much increased.

It appears that the position of the Diaphragm in the thorax depends upon three main factors, viz.: (1) the elastic retraction of the lung-tissue, tending to pull it upwards; (2) the pressure exerted on its under surface by the viscera: this naturally tends to be a negative pressure, or downward suction, when the patient sits or stands, and a positive, or upward pressure, when he lies; (3) the intra-abdominal tension due to the abdominal muscles. These muscles are in a state of contraction in the standing position and not in the sitting; hence the Diaphragm is pushed up higher in the former position.

Applied Anatomy.—The oblique rise of the Diaphragm from the costal margin to the level of the fifth costal cartilage on the right side, and the sixth on the left, has to be borne in mind in opening an empyema. If the drainage tube be put in too low down. when the abscess cavity contracts the Diaphragm is drawn up against and blocks the tube before the abscess is cured.

The Mechanism of Respiration

The respiratory movements must be examined during (*a*) quiet respiration, and (*b*) deep respiration.

Quiet respiration.—The first and second pairs of ribs are fixed by the resistance of the cervical structures; the last pair, and through them the eleventh, by the Quadratus lumborum. The other ribs are elevated, so that the first two intercostal spaces are diminished while the others are increased in width. It has already been shown (p. 450) that elevation of the third, fourth, fifth and sixth ribs leads to an increase in the anteroposterior and transverse diameters of the thorax: the vertical diameter is increased by the descent of the diaphragmatic dome so that the lungs are expanded in all directions except backwards and upwards. Elevation of the eighth, ninth and tenth ribs is accompanied by a lateral and backward movement, leading to an increase in the transverse diameter of the upper part of the abdomen; the elasticity of the anterior abdominal wall allows a slight increase in the anteroposterior diameter of this part, and in this way the decrease in the vertical diameter of the abdomen is compensated and space provided for its displaced viscera. Expiration is effected by the elastic recoil of the thoracic walls, and by the action of the abdominal muscles, which push back the displaced abdominal viscera.

Deep respiration.—All the movements of quiet respiration are here carried out, but to a greater extent. In deep respiration the shoulders and the vertebral borders of the scapulæ are fixed and the Trapezius, Serratus anterior, Pectoral, and Latissimus dorsi muscles are called into play. The Scaleni are in strong action, and the Sternomastoids also assist when the head is fixed, by drawing up the sternum, and by fixing the clavicles. The first ribs are therefore no longer stationary, but are raised with the sternum; with them all the other ribs except the last are raised to a higher level. In conjunction with the increased descent of the Diaphragm this provides for a considerable augmentation of all the thoracic diameters. The anterior abdominal muscles come into action so that the umbilicus is drawn upwards and backwards, but this allows the Diaphragm to exert a more powerful influence on the lower ribs; the transverse diameter of the upper part of the abdomen is greatly increased and the infrasternal angle opened out. The deeper muscles of the back, e.g. the Serrati posteriores superiores and the Sacrospinales and their continuations, are also brought into action; the thoracic curve of the vertebral column is partially straightened, and the whole column, above the lower lumbar vertebræ, drawn backwards. This increases the anteroposterior diameters of the thorax and upper part of the abdomen and widens the intercostal spaces. Deep expiration is effected by the recoil of the thoracic walls and by the contraction of the anterolateral muscles of the abdominal wall.

Halls Dally (*loc. cit.*) gives the following figures as representing the average changes which occur during deepest possible respiration. The manubrium sterni moves 30 mm. in an upward and 14 mm. in a forward direction; the width of the infrasternal angle, at a

level of 30 mm. below the articulation between the body of the sternum and the xiphoid process, is increased by 26 mm.; the umbilicus is retracted and drawn upwards for a distance of 18 mm.

Applied Anatomy.—The changes in the height of the Diaphragm during alterations in posture explain why patients suffering from severe dyspnœa are most comfortable and least short of breath when they sit up. In unilateral disease of the pleura or lungs interference with the position or movement of the Diaphragm can generally be observed skiagraphically. Middleton,* by estimating the vital capacity in cases where the action of the Diaphragm was impaired by thoracic wounds or empyema, concludes that the normal diaphragmatic contraction is responsible for 60 per cent. of the respiratory exchange in deep breathing.

IV. The Muscles of the Abdomen

The muscles of the abdomen may be divided into anterolateral and posterior groups.

1. The Anterolateral Muscles

Obliquus externus. Transversus.
Obliquus internus. Rectus.
Pyramidalis.

The **superficial fascia** of the abdomen consists, over the greater part of the abdominal wall, of a single layer containing a variable amount of fat; but near the groin the fascia is easily divisible into two layers, between which are found the superficial vessels, nerves, and inguinal lymph-glands.

The superficial layer of the fascia is thick, areolar in texture, and contains in its meshes a varying quantity of fat. Below, it passes over the inguinal ligament, and is continuous with the superficial fascia of the thigh. In the male this layer is continued over the penis and outer surface of the spermatic cord to the scrotum. As it passes to the scrotum it changes its characteristics, becoming thin, destitute of adipose tissue, and of a pale reddish colour; in the scrotum it acquires some involuntary muscular fibres and forms the *dartos* muscle. From the scrotum it may be traced backwards into continuity with the superficial fascia of the perineum. In the female it is continued from the abdomen into the labia majora.

The deep layer of the fascia, thinner and more membranous than the superficial layer, contains a considerable quantity of elastic fibres. It is loosely connected by areolar tissue to the aponeurosis of the External oblique muscle, but in the median plane it is more intimately adherent to the linea alba and to the symphysis pubis, and is prolonged on to the dorsum of the penis, forming the *fundiform ligament*; above, it is continuous with the superficial fascia over the rest of the trunk; below and laterally, it blends with the fascia lata of the thigh a little below and parallel with the inguinal ligament (fig. 596); below and medially, it is continued over the penis and spermatic cord to the scrotum, where it helps to form the dartos muscle. From the scrotum it may be traced backwards into continuity with the membranous layer of the superficial fascia of the perineum (p. 577). In the female it is continued into the labia majora and thence to the fascia of the perineum.

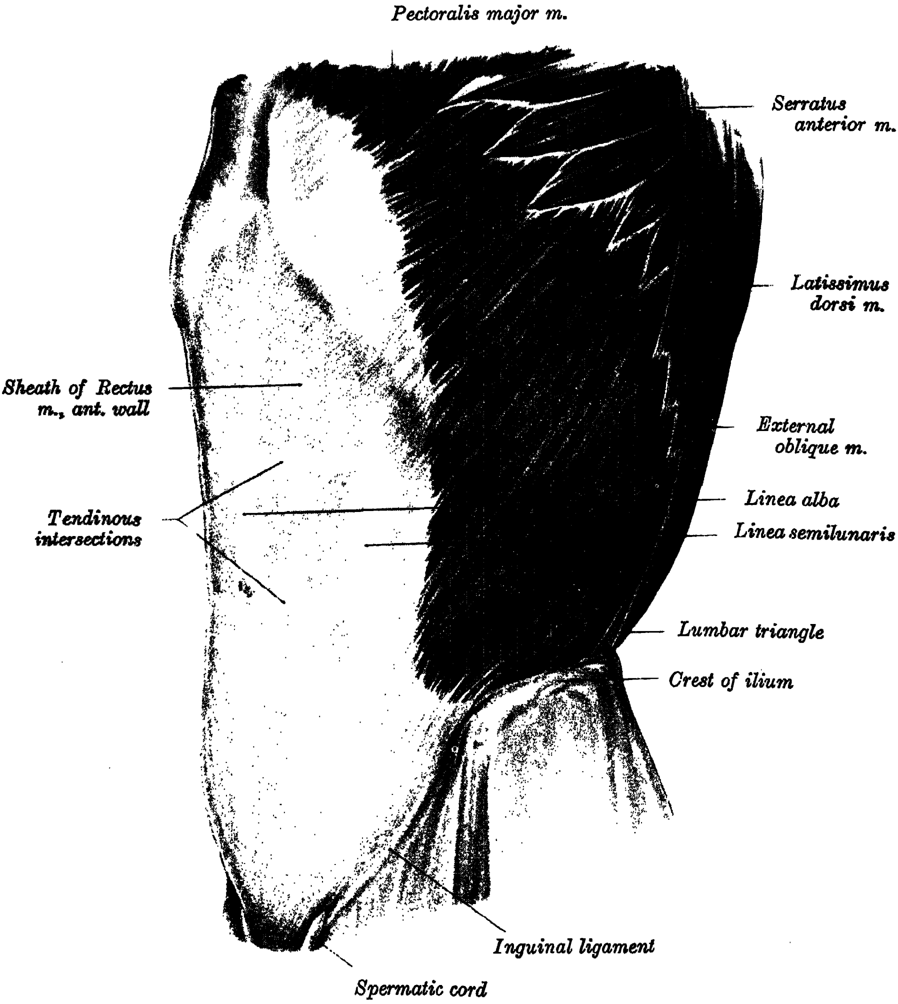
The **Obliquus externus abdominis** (fig. 595), situated on the lateral and anterior parts of the abdomen, is the largest and the most superficial of the three flat muscles in this region. It arises, by eight fleshy slips, from the external surfaces and inferior borders of the lower eight ribs; these slips interdigitate with the slips of origin of the Serratus anterior and Latissimus dorsi, and are arranged in an oblique line which runs downwards and backwards, the upper ones being attached close to the cartilages of the corresponding ribs, the lowest to the apex of the cartilage of the last rib, the middle ones to the ribs at some distance from their cartilages. From these attachments the fleshy fibres proceed in various directions. Those from the lower two ribs pass nearly vertically downwards, and are inserted into the anterior half or more of the outer lip of the ventral segment of the iliac crest (p. 368); the middle and upper fibres, directed downwards and forwards, end in an aponeurosis, opposite a line drawn vertically from the ninth costal cartilage to a little below the level of

* *American Journal of Medical Science*, 1923, p. 222.

the umbilicus, and then inclining laterally to the anterior superior iliac spine. None of the fleshy fibres of the muscle extend downwards beyond a line drawn from the anterior superior iliac spine to the umbilicus. The posterior border of the muscle is free.

The *aponeurosis* of the External oblique muscle is a thin but strong membranous structure, the fibres of which are directed downwards and medially. In the median plane its fibres end in the *linea alba* (fig. 595), a tendinous raphe which stretches from the xiphoid process to the symphysis pubis. There it is

FIG. 595.—The left Obliquus externus abdominis.



continuous with the aponeurosis of the corresponding muscle of the opposite side and the two together cover the front of the abdomen. Above and laterally, it is covered by, and gives origin to, the lower fibres of the Pectoralis major; below, its fibres are closely aggregated together, and extend obliquely across from the anterior superior iliac spine to the pubic tubercle and the pectineal line.

The margin of that portion of the aponeurosis which extends between the anterior superior iliac spine and the pubic tubercle is a thick band, folded backwards upon itself to present a grooved upper surface, and continuous below with the fascia lata of the thigh; it is called the *inguinal ligament*. A small portion is reflected from the medial part of the inguinal ligament, and is attached to the pectineal line of the pubis; it is called the *pectineal part of the inguinal ligament* (lacunar ligament). From the attachment of the latter a few fibres pass upwards and medially, behind the superior crus of the superficial inguinal ring

(subcutaneous inguinal ring), to the linea alba; they diverge as they ascend, and form a thin triangular fibrous band, which is called the *reflected part of the inguinal ligament* (fig. 602).

The complete insertion of the muscle can now be summarised. The highest fibres are inserted into the xiphoid process; the succeeding fibres into the linea alba, the upper border of the pubic symphysis and the adjoining part of the pubic crest, the pubic tubercle and the adjoining part of the pectineal line; and the lowest fibres into the anterior superior iliac spine and the anterior two-thirds of the outer lip of the ventral segment of the iliac crest.

FIG. 596.—A superficial dissection of the groin and the lower part of the anterior abdominal wall. Right side.

Nerve-supply.—The External oblique muscle is supplied by the anterior primary rami of the lower thoracic nerves.

Actions.—When the thorax and pelvis are fixed the External oblique muscles compress the abdominal viscera and thus assist in expelling the fæces from the rectum, the urine from the bladder, the fœtus from the uterus, and the contents of the stomach in vomiting. If the pelvis and vertebral column be fixed the muscles depress and compress the lower part of the thorax, assisting in expiration. If the pelvis alone be fixed, the trunk is bent forwards when both muscles act; if the muscle of one side act, the trunk is bent towards that side and the front of the abdomen turned towards the opposite side. If the thorax be fixed, the muscles, acting together, draw the front of the pelvis upwards and help to flex the lumbar part of the vertebral column.

Certain parts of the aponeurosis of the External oblique muscle require more detailed consideration.

The **superficial inguinal ring** (subcutaneous inguinal ring) (figs. 596, 597) is an interval in the aponeurosis, just above and lateral to the crest of the pubis. The aperture is somewhat triangular in form, and its direction is oblique, corresponding with the course of the fibres of the aponeurosis. It measures from base to apex about 2·5 cm., and across the base about 1·25 cm. Its base is formed by the crest of the pubis, and its sides by the margins of the opening in the aponeurosis, which are called the *crura of the ring*; above, the crura are

Fig. 597.—A superficial dissection of the groin and the lower part of the anterior abdominal wall. Left side.

connected by a series of curved *intercrural fibres*. The inferior crus of the ring is the stronger, and is formed by that portion of the inguinal ligament which is inserted into the pubic tubercle; it is curved so as to form a kind of groove, upon which, in the male, the spermatic cord rests. The superior crus is a thin, flat band, the fibres of which are attached to the front of the symphysis pubis, and interlace with the fibres of the opposite superior crus.

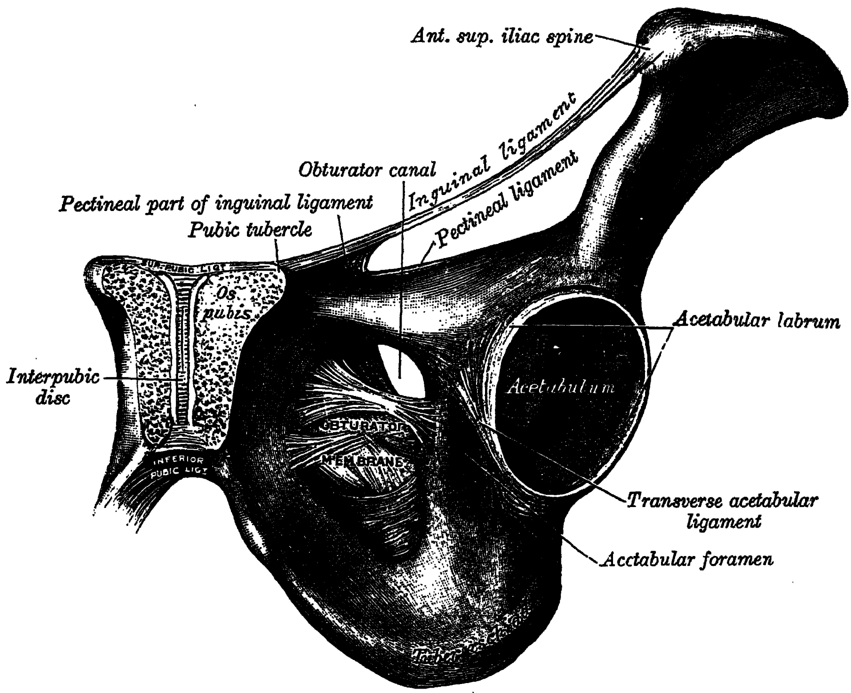
The superficial inguinal ring gives passage to the spermatic cord and ilio-inguinal nerve in the male, and to the round ligament of the uterus and the ilio-inguinal nerve in the female; it is much larger in men than in women, on account of the size of the spermatic cord.

The **intercrural fibres** are curved, tendinous fibres which arch across the lower part of the aponeurosis of the External oblique muscle, describing curves with the convexities downwards. They have received their name from the fact that they stretch across between the two crura of the superficial inguinal ring. They are much thicker and stronger at the inferior crus, where they are connected to the inguinal ligament, than superiorly, where they are inserted into the linea alba. The intercrural fibres increase the strength of the lower part of

the aponeurosis, and tend to prevent the divergence of the crura from each other; they are more strongly developed in the male than in the female. As they pass across the superficial inguinal ring they are connected together by delicate fibrous tissue, forming what is called the **external spermatic fascia** (intercrural fascia). This fascia is continued down as a tubular prolongation around the spermatic cord and testis, and forms the outermost of the coverings which enclose them. The superficial inguinal ring is seen as a distinct aperture only after the continuity between this fascia and the aponeurosis of the External oblique muscle has been severed.

The **inguinal ligament** (figs. 597, 598) is the lower border of the aponeurosis of the External oblique muscle, and stretches from the anterior superior iliac spine to the pubic tubercle. Its general direction is convex downwards towards

Fig. 598.—The left inguinal ligament.



the thigh, and it is continuous with the fascia lata. Its lateral one-half is rounded, and oblique in direction; its medial one-half gradually widens at its attachment to the pubis, is more horizontal in direction, and supports the spermatic cord.

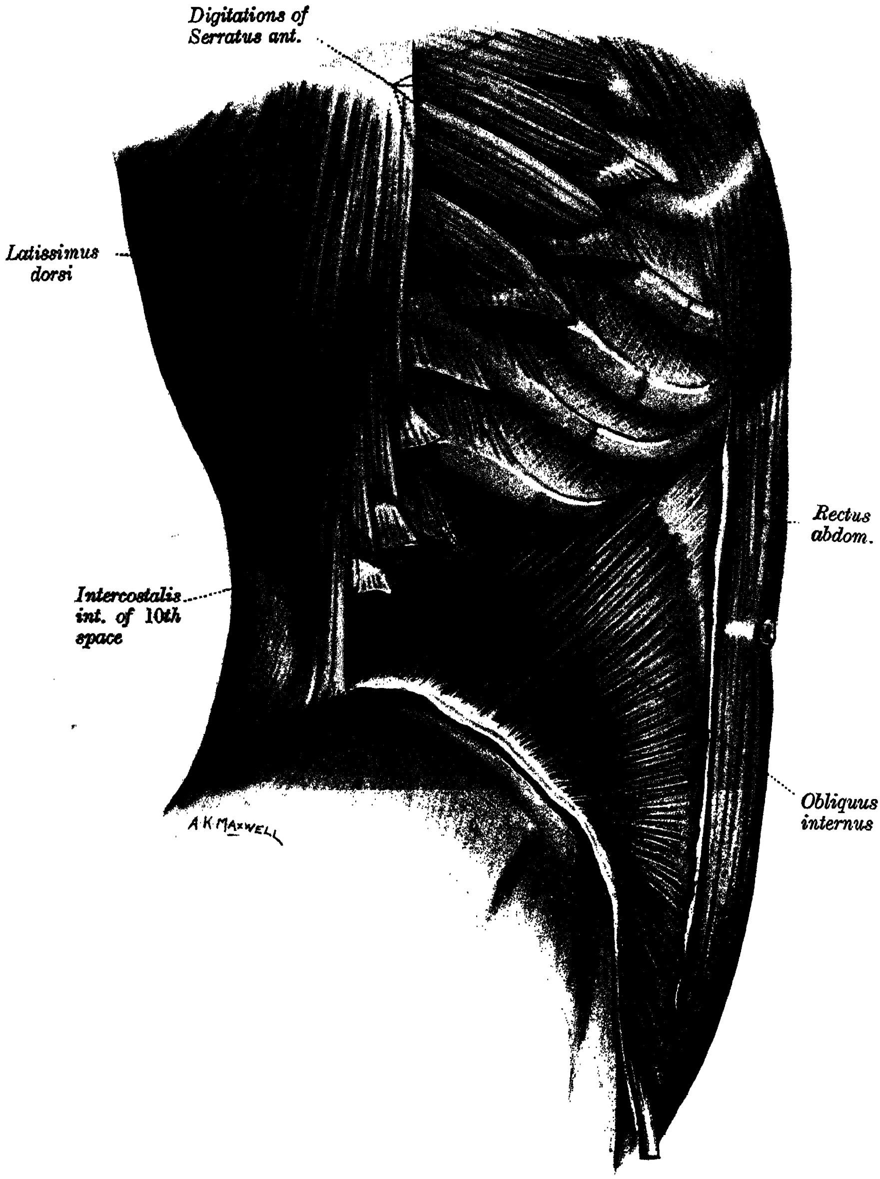
The **pectineal part of the inguinal ligament** (lacunar ligament) (fig. 598) is that portion of the aponeurosis of the External oblique muscle which passes backwards and laterally from the medial part of the inguinal ligament, and is attached to the medial end of the pectineal line. It is of a triangular form, and is almost horizontal in direction when the body is in the erect posture; it is a little larger in the male than in the female, and measures about 2 cm. from base to apex. Its base, directed laterally, is concave and thin, and forms the medial boundary of the femoral ring; its apex corresponds to the pubic tubercle. Its posterior margin is attached to the pectineal line, and is continuous with the pectineal fascia; its anterior margin is continuous with the inguinal ligament. Its surfaces are directed upwards and downwards.

The **reflected part of the inguinal ligament** (figs. 597, 602) is a triangular-shaped layer of tendinous fibres; it is formed by an expansion from the pectineal part of the inguinal ligament and the inferior crus of the superficial inguinal ring. It passes medially behind the spermatic cord, expands into a

triangular band behind the superior crus of the superficial inguinal ring and in front of the conjoint tendon (falx inguinalis aponeurotica); its fibres interlace with those of the opposite ligament at the linea alba.

The pectineal ligament (*ligament of Cooper*).—This is a strong fibrous band, which was first described by Sir Astley Cooper. It extends laterally from the

FIG. 599.—Dissection of the muscles of the side of the trunk. The External oblique muscle has been removed to show the Internal oblique, but its digitations from the ribs have been preserved. The sheath of the Rectus has been opened and its anterior wall removed. (From Quain's *Anatomy*, XI. Edition.)

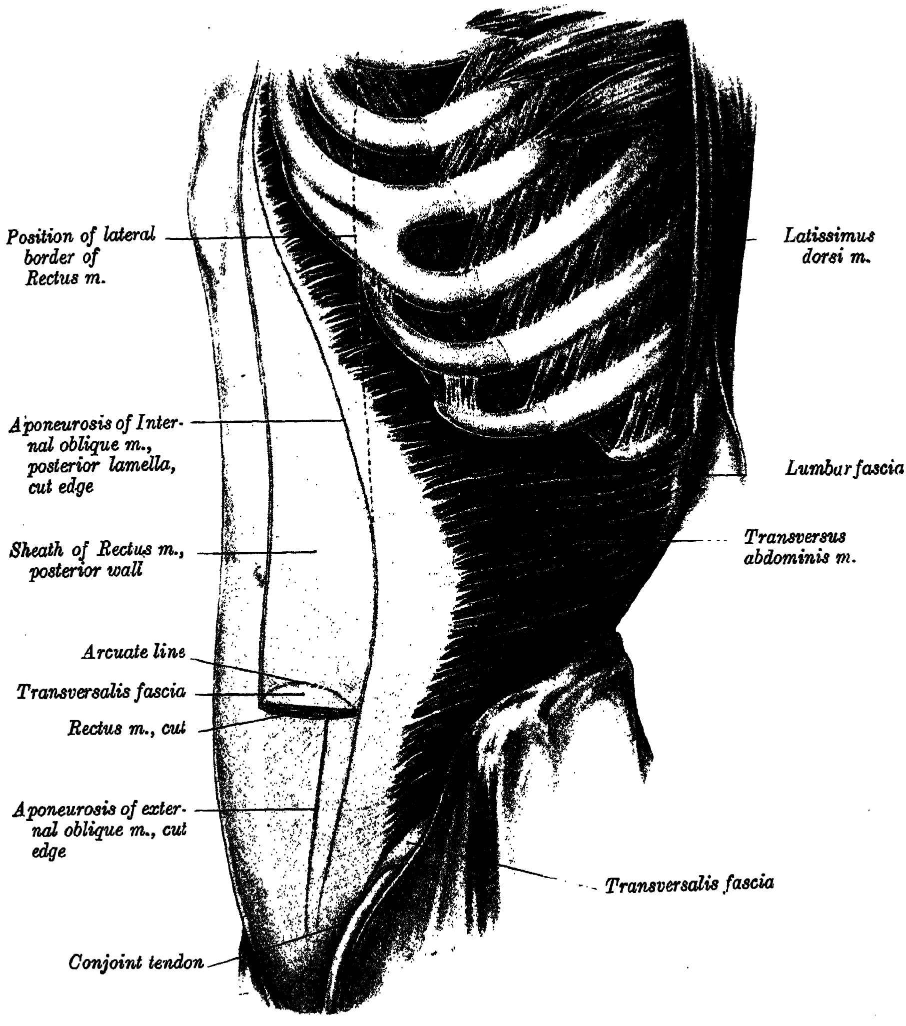


base of the pectineal part of the inguinal ligament (fig. 598) along the pectineal line, to which it is attached. It is strengthened by the pectineal fascia, and by a lateral expansion from the lower attachment of the linea alba (adminiculum lineæ albæ) (p. 570).

The **Obliquus internus abdominis** (fig. 599), which lies under cover of the External oblique, is a thinner and less bulky muscle. It arises, by fleshy fibres, from the lateral one-half of the grooved upper surface of the inguinal ligament,

from the anterior two-thirds of the intermediate area of the ventral segment of the iliac crest, and from the lumbar fascia (fig. 589). The posterior fibres ascend almost vertically, and are inserted into the inferior borders of the lower three ribs, and are there continuous with the Internal Intercostals. The fibres arising from the inguinal ligament, paler in colour than the others, arch downwards and medially across the spermatic cord in the male and the round ligament of the uterus in the female. Becoming tendinous they are inserted, conjointly

FIG. 600.—The left Transversus abdominis.



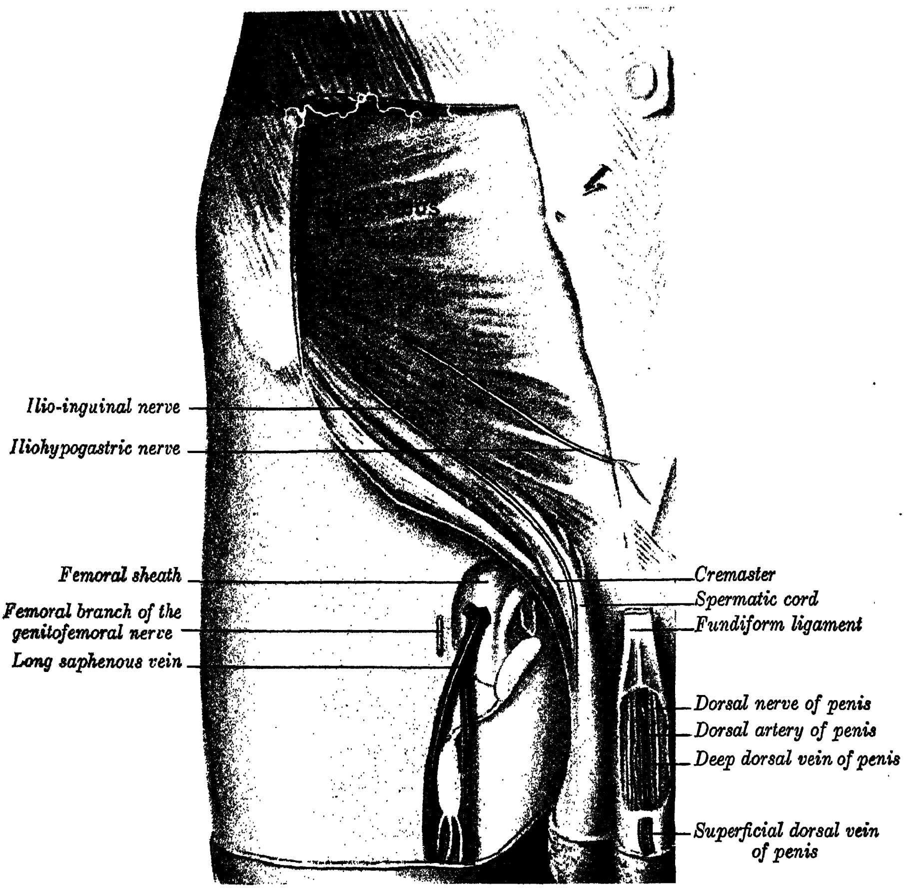
with the corresponding part of the aponeurosis of the Transversus abdominis, into the crest of the pubis and the medial part of the pectineal line, forming what is known as the *conjoint tendon* (inguinal aponeurotic falx). The rest of the fibres of the Internal oblique muscle diverge and end in an aponeurosis which gradually broadens from below upwards. The greater part of this aponeurosis splits at the lateral border of the Rectus abdominis into two lamellæ which ensheathe this muscle, and reunite at the linea alba. The anterior layer of this sheath blends with the aponeurosis of the External oblique muscle: the posterior layer fuses with the aponeurosis of the Transversus abdominis, and its upper part is attached to the cartilages of the seventh, eighth and ninth ribs.

Nerve-supply.—The Internal oblique muscle is supplied by the anterior primary rami of the lower six thoracic and the first lumbar nerves.

Actions.—The actions of the Internal oblique muscles are similar to those of the External oblique in compressing the abdomen (p. 561). Acting from below the Internal oblique muscle bends the thorax and turns the front of the abdomen towards the same side; acting from above it bends the lumbar part of the vertebral column to its own side and turns the front of the abdomen to the opposite side.

The **Cremaster** (fig. 601) is a thin muscular layer composed of a number of fasciculi which arise from the middle of the inguinal ligament, where its fibres

Fig. 601.—A dissection of the regions shown in fig. 596, but with a part of the Obliquus externus removed.



are continuous with those of the Internal oblique and also occasionally with the Transversus. It passes along the lateral side of the spermatic cord, and descends with it through the superficial inguinal ring upon the anterior and lateral surfaces of the cord, where it forms a series of loops which differ in thickness and length. At the upper part of the cord the loops are short, but they become successively longer, the longest reaching as far as the tunica vaginalis, into which a few are inserted. These loops are united together by areolar tissue, and form a thin covering over the cord and testis, named the *cremasteric fascia*. The fibres ascend along the medial and posterior surfaces of the cord, and are inserted by a small pointed tendon into the tubercle and crest of the pubis and into the front of the sheath of the Rectus abdominis.

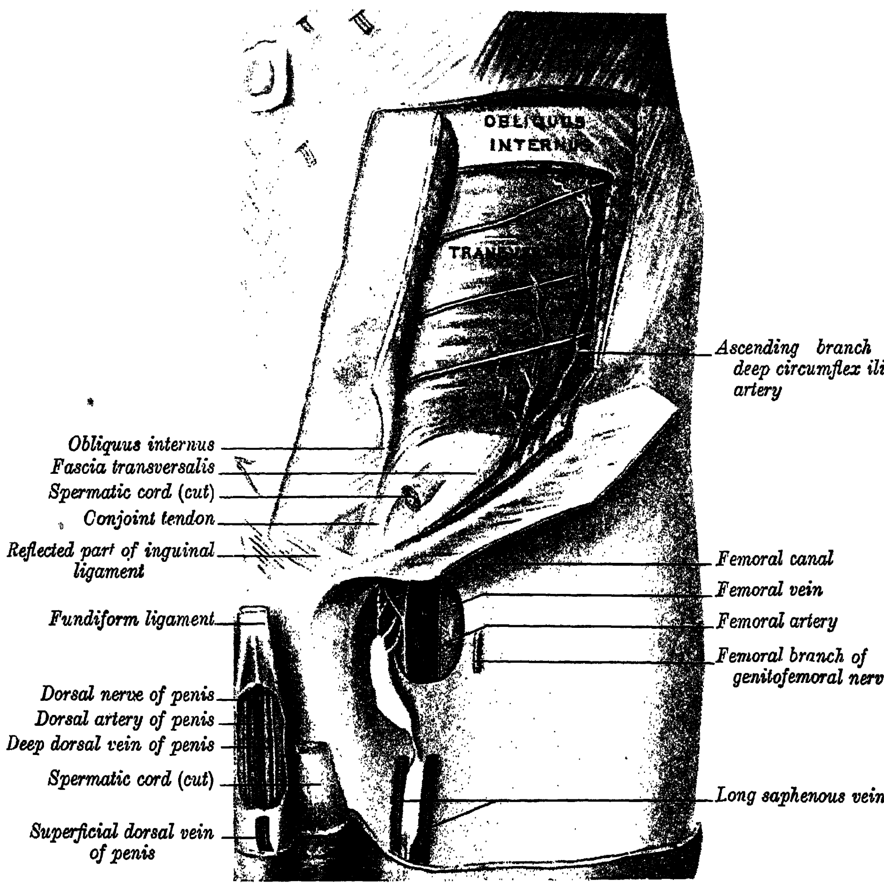
Nerve-supply.—The Cremaster is supplied by the genital (external spermatic) branch of the gemitofemoral nerve (L. 1 and 2).

Action.—The Cremaster is an involuntary muscle which pulls up the testis.

The **Transversus abdominis** (fig. 600), so called from the direction of its fibres, is the most internal of the flat muscles of the abdomen, being situated deep to

the Internal oblique. It arises by fleshy fibres from the lateral one-third of the inguinal ligament, from the anterior two-thirds of the inner lip of the ventral segment of the iliac crest, from the lumbar fascia as it extends between the iliac crest and the twelfth rib, and from the inner surfaces of the cartilages of the lower six ribs, interdigitating with the Diaphragm (fig. 592). The muscle ends in an aponeurosis, the lower fibres of which curve downwards and medially, and are inserted, together with those of the aponeurosis of the Internal oblique muscle, into the crest and pectineal line of the pubis, forming the conjoint

Fig. 602.—A dissection of the regions shown in fig. 597, but with portions of the Obliqui externus et internus removed.



tendon. The rest of the aponeurosis passes horizontally to the median plane, and is inserted into the linea alba; its upper three-fourths lie behind the Rectus abdominis and blend with the posterior lamella of the aponeurosis of the Internal oblique muscle; its lower one-fourth is in front of the Rectus. The upper muscular fibres of the Transversus abdominis are continued medially behind the Rectus abdominis (fig. 600) and the posterior lamella of the aponeurosis of the Internal oblique. Near the xiphoid process they reach to within 2 or 3 cm. of the linea alba. The muscular fibres of the Transversus abdominis run into the aponeurosis along a line which is concave medially (fig. 600), the aponeurosis being widest opposite the origin of the muscle from the lumbar fascia.

The *conjoint tendon* (falx inguinalis aponeurotica) of the Internal oblique and Transversus (fig. 602) is mainly formed by the lower part of the tendon of the Transversus, and is inserted into the crest and pectineal line of the pubis; it descends behind the superficial inguinal ring, thus serving to protect from behind what would otherwise be a weak point in the abdominal wall. The

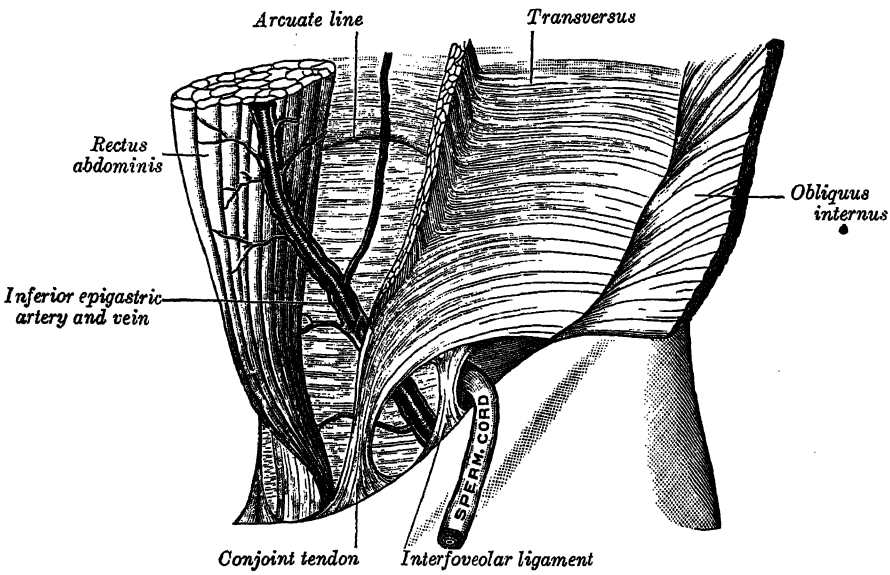
attachment to the pectineal line is frequently absent. Lateral to the conjoint tendon, an inconstant ligamentous band, named the *interfoveolar ligament* (fig. 603), may connect the lower margin of the Transversus to the superior ramus of the pubis ; it sometimes contains a few muscular fibres.

Nerve-supply.—The Transversus abdominis is supplied by the anterior primary rami of the lower six thoracic and the first lumbar nerves.

Actions.—The Transversi abdominis almost completely encircle the abdominal cavity ; in action they compress the abdominal contents.

The **Rectus abdominis** (fig. 604) is a long flat muscle, broader above than below, which extends along the whole length of the front of the abdomen, and is separated from its fellow of the opposite side by the linea alba. It arises by two tendons ; the lateral and larger is attached to the crest of the pubis : the medial interlaces with its fellow of the opposite side and is connected with the ligamentous fibres covering the front of the symphysis pubis. The muscle

Fig. 603.—The interfoveolar ligament. Anterior aspect. Modified from Braune.



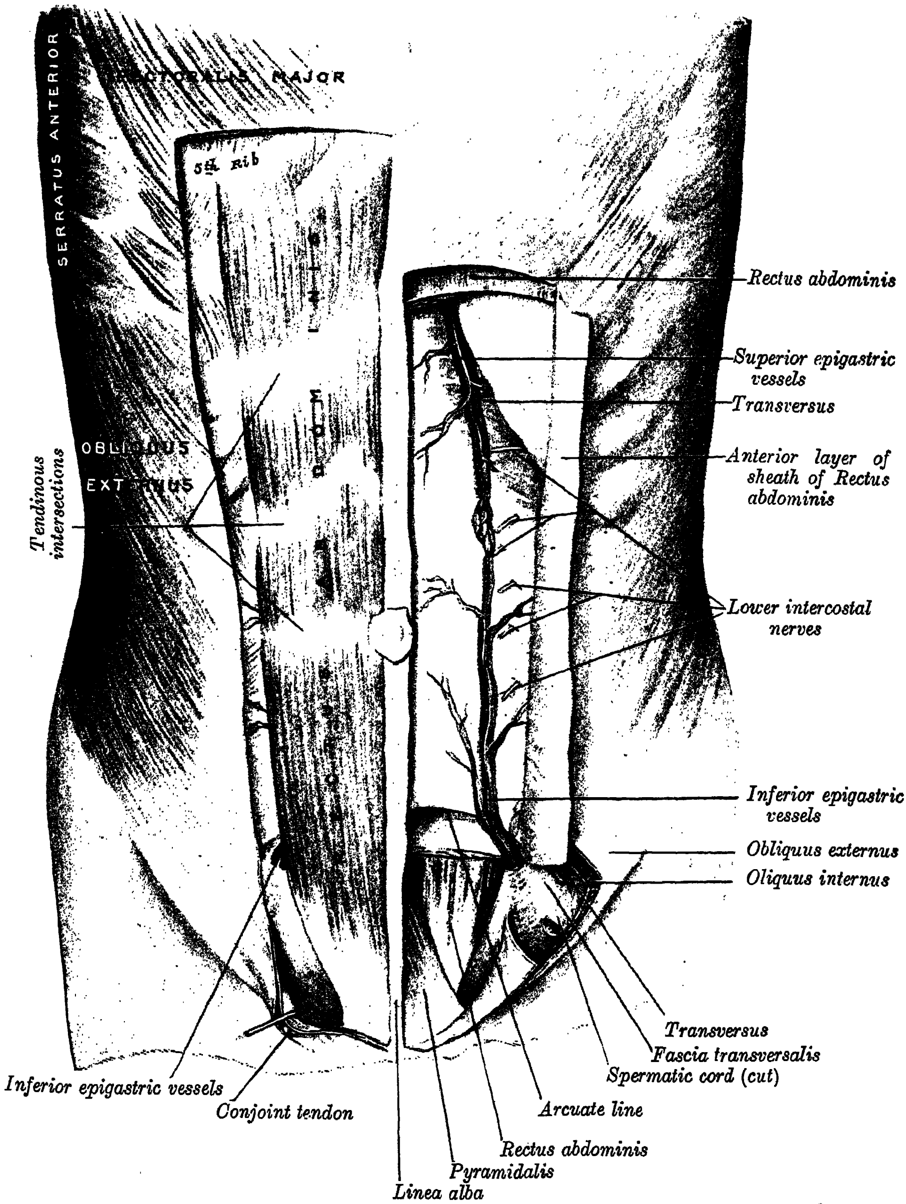
is inserted by three slips of unequal size into the cartilages of the fifth, sixth, and seventh ribs ; the most lateral fibres are usually inserted into the anterior extremity of the fifth rib ; the most medial are occasionally connected with the costoxiphoid ligaments and the side of the xiphoid process.

The rectus is intersected by three fibrous bands, named *tendinous intersections* ; one is usually situated opposite the umbilicus, another opposite the free end of the xiphoid process, and a third about midway between the xiphoid process and the umbilicus. These intersections pass transversely or obliquely across the muscle in a zigzag course ; they rarely extend completely through its substance and may pass only halfway across it ; *they are intimately adherent to the anterior lamina of the sheath of the muscle.* Sometimes one or two incomplete intersections are present below the umbilicus.

The Rectus abdominis is enclosed in a *sheath* (figs. 599, 600, 605) formed by the aponeuroses of the Obliqui and Transversus, which are arranged as follows : At the lateral margin of the Rectus, the aponeurosis of the Internal oblique divides into two lamellæ, one of which passes in front of the Rectus, blending with the aponeurosis of the External oblique, the other, behind it, blending with the aponeurosis of the Transversus, and these, joining again at the medial border of the Rectus, reach the linea alba. This arrangement of the aponeuroses exists from the costal margin to midway between the umbilicus and symphysis pubis, where the posterior wall of the sheath ends in a curved margin, named

the *arcuate line* (*linea semicircularis*) (fig. 604), the concavity of which is directed downwards. As already stated (p. 567) the muscular fibres of the upper part of the Transversus abdominis are continued behind the corresponding part of the Rectus abdominis to within 2 or 3 cm. of the linea alba (figs. 600, 604).

Fig. 604.—The right Rectus abdominis and the left Pyramidalis. The greater part of the left Rectus abdominis has been removed to show the superior and inferior epigastric vessels.



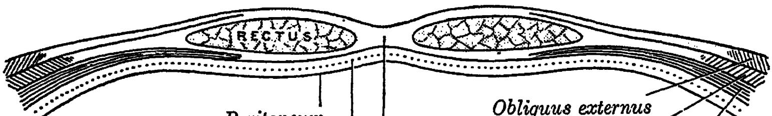
Below the level of the arcuate line the aponeuroses of all three muscles pass in front of the Rectus; those of the Transversus and Internal oblique are intimately fused together, but the aponeurosis of the External oblique is bound to them merely by loose connective tissue except in and near the median plane; behind, the Rectus is separated from the peritoneum by the transversalis fascia (fig. 606). Since the aponeuroses of the Internal oblique and Transversus only reach as high as the costal margin it follows that above this level the sheath of

the Rectus is deficient posteriorly, the muscle resting directly on the cartilages of the ribs; the front of this part of the Rectus is covered merely by the aponeurosis of the External oblique muscle.

The medial border of the muscle is closely related to the linea alba: its lateral border is marked on the surface of the anterior abdominal wall by a curved groove, termed the *linea semilunaris,* which extends from the tip of the ninth costal cartilage to the pubic tubercle. It is readily seen in a muscular subject even when the muscle is not actively contracting.

Nerve-supply.—The Rectus abdominis is supplied by the anterior primary rami of the lower six or seven thoracic nerves.

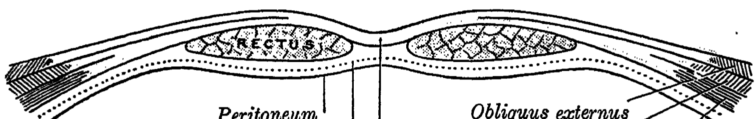
Fig. 605.—A transverse section through the anterior abdominal wall, above the umbilicus. Diagrammatic.



Actions.—The Rectus abdominis acting from above elevates the front of the pelvis; acting from below it depresses the thorax, and in continued action flexes the vertebral column. The two muscles are also powerful compressors of the abdominal viscera.

The **Pyramidalis** (fig. 604) is a triangular muscle, placed at the lower part of the abdomen, in front of the Rectus abdominis and within the sheath of that muscle. It arises by tendinous fibres from the front of the pubis and from the ligamentous fibres in front of the symphysis; the fleshy portion of the muscle passes upwards, diminishing in size as it ascends, and ends in a pointed extremity which is inserted into the linea alba midway between the umbilicus and pubis, but may extend to a higher level. This muscle may be larger on one side than on the other, or may be wanting on one or both sides.

Fig. 606.—A transverse section through the anterior abdominal wall, below the arcuate line. Diagrammatic.



Besides the Rectus and Pyramidalis, the sheath of the Rectus contains the superior and inferior epigastric arteries, and the terminal portions of the lower intercostal nerves.

Nerve-supply.—The Pyramidalis is supplied by the subcostal nerve (T. 12).

Action.—The Pyramidalis is a tensor of the linea alba.

The **linea alba** (figs. 595, 605) is a tendinous raphe stretching between the xiphoid process and the symphysis pubis. It is placed between the medial borders of the Recti, and is formed by the interlacement of the fibres of the aponeuroses of the Obliqui and Transversi. It is narrow below, corresponding to the linear interval existing between the Recti; but broader above, where these muscles diverge from each other. Its lower end has a double attachment—its superficial fibres passing in front of the medial heads of the Recti to the front of the symphysis pubis, while its deeper fibres form a triangular lamella, attached behind the Recti to the posterior surface of the crest of the pubis, and named the *adminiculum lineæ albæ.* The linea alba presents apertures for the passage of vessels and nerves; in the fœtus the umbilicus transmits the umbilical vessels, but it is closed a few days after birth.

The **transversalis fascia** is a thin membrane which lies between the inner surface of the Transversus muscle and the extraperitoneal fat. It forms part of the general layer of fascia lining the abdominal parietes, and is continuous with the iliac and pelvic fasciæ. In the inguinal region it is thick and dense in structure, and is joined by fibres from the aponeurosis of the Transversus, but it becomes thin as it ascends to the Diaphragm, and blends with the fascia covering the under surface of this muscle. Behind, it is lost on the surface of the lumbar (lumbodorsal) fascia, with which it blends. Below, it has the following attachments : posteriorly, to the whole length of the iliac crest, between the origins of the Transversus and Iliacus ; between the anterior superior iliac spine and the femoral vessels it is connected to the posterior margin of the inguinal ligament, and is there continuous with the iliac fascia. Medial to the femoral vessels it is thin and is fixed to the pectineal line of the pubis, behind the conjoint tendon, with which it is united ; it descends in front of the femoral vessels to form the anterior wall of the femoral sheath. The spermatic cord in the male, and the round ligament of the uterus in the female, pass through the transversalis fascia at a spot called the *deep inguinal ring* (abdominal inguinal ring). This opening is not visible externally since the transversalis fascia is prolonged on these structures as the *internal spermatic fascia*.

The **deep inguinal ring** (abdominal inguinal ring) is situated in the transversalis fascia, midway between the anterior superior iliac spine and the symphysis pubis, and 1·25 cm. above the inguinal ligament. It is of an oval form, the long axis of the oval being vertical ; it varies in size in different subjects, and is much larger in the male than in the female. It is related above to the arched lower margin of the Transversus abdominis, and medially to the inferior epigastric vessels and the interfoveolar ligament, when that structure is present. It transmits the spermatic cord in the male and the round ligament of the uterus in the female. From its circumference a thin funnel-shaped membrane, named the *internal spermatic fascia*, is continued as a covering on the spermatic cord and testis.

The **inguinal canal** contains the spermatic cord and the ilio-inguinal nerve in the male, and the round ligament of the uterus and the ilio-inguinal nerve in the female. It is an oblique canal about 4 cm. long, slanting downwards and medially, and placed parallel with, and a little above, the inguinal ligament ; it extends from the deep (abdominal) inguinal ring to the superficial (subcutaneous) inguinal ring. It is bounded *in front* throughout its whole length by the skin, superficial fascia, and aponeurosis of the External oblique, and in its lateral one-third by the fleshy fibres of origin of the Internal oblique muscle ; *behind*, by the reflected part of the inguinal ligament, the conjoint tendon, and the transversalis fascia, which separate it from the extraperitoneal connective tissue and the peritoneum ; *above*, by the arched fibres of the Internal oblique and Transversus abdominis ; *below*, by the union of the transversalis fascia with the inguinal ligament, and at its medial end by the pectineal part of the inguinal ligament (lacunar ligament).

The presence of the canal weakens the lower part of the anterior abdominal wall, but the weakness thus produced is compensated for partly by the obliquity of the canal and partly by the arrangement of the constituent parts of its walls. Owing to the oblique direction of the canal the two inguinal rings do not lie opposite to one another, and increases in the intra-abdominal pressure exercise their effect not only at the deep inguinal ring but also on the posterior wall of the canal so as to approximate it to the anterior wall. The posterior wall of the canal is strengthened by the conjoint tendon and the reflected part of the inguinal ligament precisely opposite to the superficial inguinal ring, and the fleshy fibres of the Internal oblique muscle take part in the formation of the anterior wall, where it lies opposite to the deep inguinal ring.

The **extraperitoneal connective tissue.**—Between the peritoneum and the inner surface of the general layer of the fascia which lines the interior of the abdominal and pelvic cavities, there is a considerable amount of connective tissue, termed the *extraperitoneal tissue*.

The extraperitoneal tissue varies in quantity in different situations. It is especially abundant on the posterior wall of the abdomen, and particularly around the kidneys, where it contains much fat. It is scanty on the antero-

lateral wall of the abdomen, except in the pubic region and above the iliac crest; there is a considerable amount in the pelvis.

2. The Posterior Muscles of the Abdomen

Psoas major.	Iliacus.
Psoas minor.	Quadratus lumborum.

The Psoas major, the Psoas minor, and the Iliacus, with the fasciæ covering them, are described with the muscles of the lower limb (pp. 621 to 623).

The **fascia covering the Quadratus lumborum** is the anterior layer of the lumbar fascia (p. 546). It is attached, medially, to the anterior surfaces of the transverse processes of the lumbar vertebræ; below, to the iliolumbar ligament; above, to the apex and lower border of the last rib. The upper margin of this fascia, which extends from the transverse process of the first lumbar vertebra to the apex and lower border of the last rib, constitutes the lateral arcuate ligament (lateral lumbocostal arch) (p. 555). Laterally, the fascia blends with the fused posterior and middle layers of the lumbar fascia (fig. 589).

The **Quadratus lumborum** (figs. 590, 638) is irregularly quadrilateral in shape, and broader below than above. It arises by aponeurotic fibres from the iliolumbar ligament and the adjacent portion of the iliac crest for about 5 cm., and is inserted into the medial one-half of the lower border of the last rib, and by four small tendons into the apices of the transverse processes of the upper four lumbar vertebræ. Occasionally a second portion of this muscle is found in front of the preceding; it arises from the upper borders of the transverse processes of the lower three or four lumbar vertebræ, and is inserted into the lower margin and the lower part of the anterior surface of the last rib.

In front of the Quadratus lumborum are the colon, the kidney, the Psoas major et minor, and the Diaphragm; the subcostal, iliohypogastric, and ilio-inguinal nerves lie in front of the fascia which covers the muscle but are bound down to it by the continuation medially of the transversalis fascia.

Nerve-supply.—The Quadratus lumborum is supplied by the anterior primary rami of the twelfth thoracic and upper three or four lumbar nerves.

Actions.—The Quadratus lumborum draws down the last rib, and acts as a muscle of inspiration by helping to fix the origin of the Diaphragm. If the thorax and vertebral column are fixed, it may act upon the pelvis, raising it towards its own side when only one muscle is put in action; and when both muscles act together they help to extend the lumbar part of the vertebral column.

V. The Muscles of the Pelvis

Obturator internus.	Levator ani.
Piriformis.	Coccygeus.

The muscles within the pelvis may be divided into two groups: (1) the Piriformis and the Obturator internus, which are described with the muscles of the lower limb (pp. 633, 635); (2) the Levator ani and the Coccygeus, which, with the corresponding muscles of the opposite side, form the *pelvic diaphragm*. The classification of the two groups under a common heading is convenient in connexion with the fasciæ investing the muscles. These fasciæ are closely related to one another and to the deep fascia of the perineum, and in addition are connected with the fascial coverings of the pelvic viscera; it is customary therefore to describe them together under the term *pelvic fascia*.

Pelvic fascia.—The fascia of the pelvis may be resolved into: (A) the fascial sheaths of the pelvic muscles; (B) the fascial sheaths of the pelvic viscera (see section on Splanchnology).

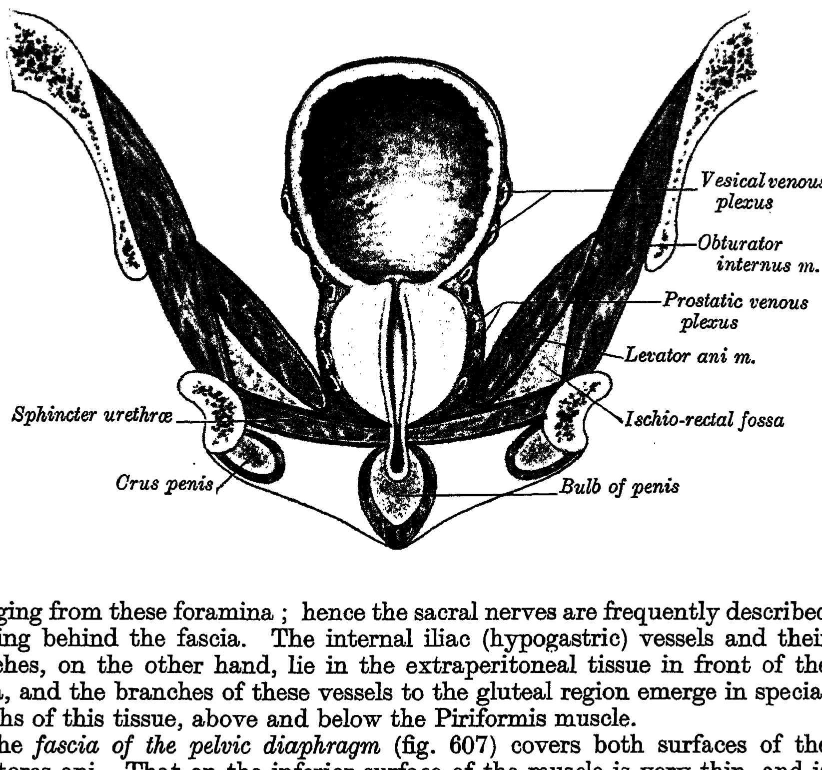
The *fascia of the Obturator internus* covers the pelvic surface of the muscle, and is attached round the margin of its origin. Above, it is connected to the posterior part of the arcuate line of the hip-bone, and is there continuous with the iliac fascia. In front of this, as it follows the line of origin of the

Obturator internus, it gradually separates from the iliac fascia, and the continuity between the two is retained only through the periosteum. It arches below the obturator vessels and nerve, completing the obturator canal, and at the front of the pelvis is attached to the back of the body of the pubis. The lower part of the obturator fascia forms the lateral wall of the ischiorectal fossa, and is attached inferiorly to the falciform process of the sacro-tuberous ligament and to the pubic arch; at the pubic arch it is continuous with the fascia on the deep surface of the Deep transversus perinei and the Sphincter urethræ. Behind, it is indirectly continuous with the fascia of the Piriformis.

The internal pudendal vessels and their accompanying nerves are placed in the lateral wall of the ischiorectal fossa, and are enclosed in a special sheath of the fascia, named the *pudendal canal.*

The *fascia of the Piriformis* is very thin and is attached to the front of the sacrum around the margins of the anterior sacral foramina. At its sacral attachment it comes into intimate association with and ensheathes the nerves

FIG. 607.—A coronal section through the pelvis, showing the arrangement of the fasciæ and the sheath of the prostate. Diagrammatic.



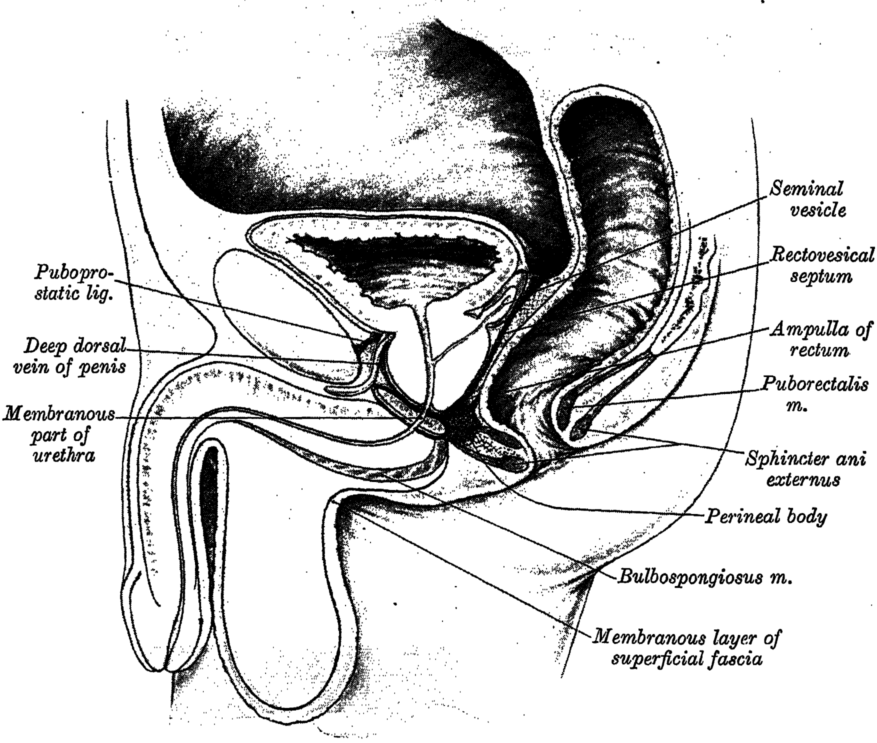
emerging from these foramina; hence the sacral nerves are frequently described as lying behind the fascia. The internal iliac (hypogastric) vessels and their branches, on the other hand, lie in the extraperitoneal tissue in front of the fascia, and the branches of these vessels to the gluteal region emerge in special sheaths of this tissue, above and below the Piriformis muscle.

The *fascia of the pelvic diaphragm* (fig. 607) covers both surfaces of the Levatores ani. That on the inferior surface of the muscle is very thin, and is known as the *anal fascia*; it forms the medial wall of the ischiorectal fossa, and above is continuous with the obturator fascia along the line of origin of the Levator ani; it is continuous below with the fascia on the Sphincter urethræ and the Sphincter ani externus. On the lateral side the layer covering the upper surface of the Levator ani follows the line of origin of the muscle, and is therefore somewhat variable. In front it is attached to the back of the symphysis pubis about 2 cm. above its lower border, and can be traced laterally across the back of the superior ramus of the pubis for a distance of 1·25 cm., when it reaches the obturator fascia. It blends with this fascia along a line which pursues a somewhat irregular course to the spine of the ischium. The irregularity of this line is explained by the fact that whereas in lower mammals the Levator ani arises posteriorly from the pelvic brim, in man it has descended to a lower level and arises from the obturator fascia. In some cases tendinous fibres of origin extend up towards, and may reach, the pelvic brim, carrying the fascia with them.

Internally the fascia covering the upper surface of the pelvic diaphragm blends with the fascial sheaths of the pelvic viscera. The fascia covering that part of the Obturator internus which lies above the origin of the Levator ani is therefore a composite structure and includes, (*a*) the obturator fascia, (*b*) the fascia of the Levator ani, and (*c*) the degenerated fibres of origin of the Levator ani.

At the level of a line extending from the lower part of the symphysis pubis to the spine of the ischium there is a thickened whitish band in this upper layer of the fascia of the pelvic diaphragm. It is termed the *tendinous arch* of the pelvic fascia, and marks the line of attachment of the lateral true ligament of the urinary bladder. Anteriorly the fascia forms two thickened bands, named the *puboprostatic ligaments*, one on each side of the median plane.

FIG. 608.—A median sagittal section through the pelvis, showing the arrangement of the fasciæ. Diagrammatic.

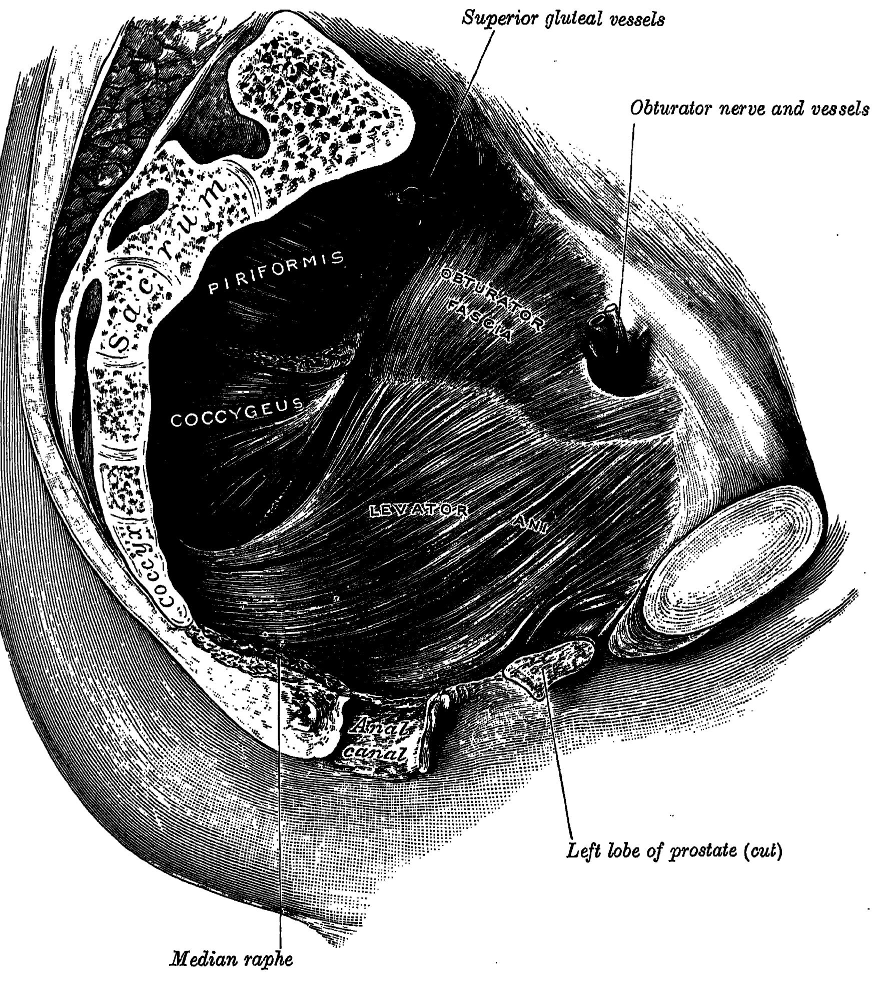


The **Levator ani** (fig. 609) is a broad, thin muscle; it is attached to the inner surface of the side of the false (lesser) pelvis, and unites with its fellow of the opposite side to form the greater part of the floor of the pelvic cavity. It arises, in front, from the pelvic surface of the body of the pubis lateral to the symphysis; behind, from the inner surface of the spine of the ischium; and between these two points, from the obturator fascia. Posteriorly this origin from the obturator fascia corresponds, more or less closely, with the tendinous arch of the pelvic fascia, but in front, the muscle arises from the fascia at a varying distance above the arch, in some cases reaching nearly as high as the canal for the obturator vessels and nerve. The fibres pass towards the median plane with varying degrees of obliquity. (*a*) The most anterior fibres sweep backwards and downwards across the side of the prostate to be inserted into the perineal body (central point of the perineum) (p. 577). They constitute the *Levator prostatæ* in the male, but in the female they cross the side of the vagina to reach their insertion, and so constitute an additional and important sphincter for that structure. (*b*) The succeeding fibres pass backwards and downwards across the side of the prostate and the upper end of the anal canal, and turn medially at the anorectal flexure to become continuous with the corresponding

fibres of the opposite side, but a number of them are lost in the wall of the anal canal. This part of the muscle is termed the *Puborectalis*. (*c*) The remaining fibres are inserted into the side of the last two segments of the coccyx and into a median fibrous raphe which stretches between the coccyx and the anorectal flexure.

Morphologically, the Levator ani may be divided into Iliococcygeus and Pubococcygeus. The *Iliococcygeus* arises from the ischial spine and from the posterior part of the tendinous arch of the pelvic fascia, and is attached to the coccyx and the median raphe; it

Fig. 609.—The left Levator ani. Pelvic surface.



is usually thin, and may fail entirely or be replaced largely by fibrous tissue. An accessory slip at its posterior part is sometimes named the *Iliosacralis*. The *Pubococcygeus* arises from the back of the pubis and from the anterior part of the obturator fascia, and is directed backwards almost horizontally along the side of the anal canal. Between the coccyx and the anal canal the Pubococcygei come together and form a thick, fibromuscular layer lying on the raphe formed by the Iliococcygei. In lower mammals both muscles are inserted only into the caudal vertebræ. The iliococcygeus is responsible for side to side movements of the tail, and the Pubococcygeus draws it downwards and forwards between the hind limbs. The gradual disappearance of the tail sets free these muscles to meet the demands for a more complete pelvic floor made by the gradual adoption of the erect attitude.

Relations.—The *upper* or *pelvic surface* of the Levator ani is separated by its covering fascia from the bladder, prostate, rectum, and peritoneum. Its *lower* or *perineal surface* forms the medial boundary of the ischiorectal fossa, and is covered by the anal fascia. Its *posterior border* is free and separated from the Coccygeus muscle by areolar tissue. Its

anterior border is separated from the muscle of the opposite side by a triangular space, through which the urethra and, in the female, the vagina pass from the pelvis.

Nerve-supply.—The Levator ani is supplied by a branch from the fourth sacral nerve and by a branch which arises either from the perineal, or from the inferior hæmorrhoidal, division of the pudendal nerve.

Actions.—The Levatores ani constrict the lower end of the rectum and vagina and steady the perineal body (central point of the perineum). Together with the Coccygei they form a muscular diaphragm which supports the pelvic viscera and opposes itself to the downward thrust produced by any increase in the intra-abdominal pressure.

The **Coccygeus** (fig. 609) is situated behind the Levator ani. It is a triangular sheet of muscular and tendinous fibres, arising by its apex from the pelvic surface of the spine of the ischium and from the sacrospinous ligament, and inserted by its base into the margin of the coccyx and into the side of the lowest piece of the sacrum. It assists the Levator ani and Piriformis in closing the posterior part of the outlet of the pelvis.

Nerve-supply.—The Coccygeus is supplied by a branch from the fourth and fifth sacral nerves.

Actions.—The Coccygei pull forward and support the coccyx, after it has been pressed backwards during defæcation or parturition.

Applied Anatomy.—Injury to the muscles forming the pelvic floor occurs not infrequently during parturition. When the perineal body (p. 577) has been torn through, and has not been repaired satisfactorily, the contraction of the anterior fibres of the Levator ani increases instead of diminishing the normal gap in the pelvic floor, and prolapse of the uterus results ; in severe cases the ovaries, bladder and rectum may also prolapse.

VI. The Muscles of the Perineum

The perineum corresponds to the outlet of the pelvis. Its deep boundaries are—in front, the pubic arch and the inferior pubic ligament ; behind, the tip of the coccyx ; and on each side the inferior ramus of the pubis and the ramus of the ischium, the ischial tuberosity and the sacrotuberous ligament. The space within these boundaries is somewhat lozenge-shaped. On the surface of the body the perineum is limited by the scrotum in front, the buttocks behind, and the medial sides of the thighs laterally. A line drawn transversely in front of the ischial tuberosities divides the space into two portions. The posterior contains the termination of the anal canal, and is known as the *anal region* ; the anterior contains the external urogenital organs, and is termed the *urogenital region.*

The muscles of the perineum may therefore be divided into two groups :

1. Those of the anal region.
2. Those of the urogenital region : A, In the male ; B, In the female.

1. The Muscles of the Anal Region

Sphincter ani externus.

The **superficial fascia** is very thick, areolar in texture, and contains much fat in its meshes. On each side a pad of fatty tissue extends deeply between the Levator ani and Obturator internus into a space known as the *ischiorectal fossa.*

The **deep fascia** forms the lining of the ischiorectal fossa ; it comprises the anal fascia, and that part of the obturator fascia which lies below the origin of Levator ani.

Ischiorectal fossa.—The fossa is somewhat wedge-shaped, with its base directed to the surface of the perineum, and its thin edge at the line of meeting of the obturator and anal fasciæ. It is bounded medially by the Sphincter ani externus and the anal fascia ; laterally, by the tuberosity of the ischium and the obturator fascia ; anteriorly, by the perineal membrane (inferior fascia of the urogenital diaphragm) ; posteriorly, by the Gluteus maximus and the sacro-

tuberous ligament. The inferior rectal vessels and the inferior hæmorrhoidal nerve cross the space transversely from the lateral to the medial side; the perineal and perforating cutaneous branches of the sacral plexus are found in the posterior part of the fossa; while from the anterior part the scrotal (or labial) vessels and nerves emerge. The internal pudendal vessels and pudendal nerve lie on the lateral wall of the fossa, in the pudendal canal (p. 573). The fossa is filled with fatty tissue, across which numerous fibrous bands extend.

The **Sphincter ani externus** (figs. 610, 612) is a flat sheet of muscular fibres, elliptical in shape and intimately adherent to the skin surrounding the anus. It measures from 8 to 10 cm. in length and is about 2·5 cm. in width opposite the anus. It consists of two portions, superficial and deep. The *superficial portion* constitutes the chief part of the muscle, and arises by a narrow tendinous band from the tip of the coccyx; the muscle consists of two flattened sheets which pass one on each side of the anus and meet in front to be inserted into the perineal body (central tendinous point of the perineum), joining with the Transversus perinei superficialis, the Levator ani, and the Bulbospongiosus (Bulbocavernosus). The *deep portion* forms a complete sphincter to the anal canal. Its fibres surround the canal, closely applied to the Puborectalis and the Sphincter ani internus, and in front blend with the other muscles at the perineal body. In a considerable proportion of cases the fibres decussate in front of the anus, and are continuous with the Transversi perinei superficiales. The upper edge of the muscle is ill-defined, since it receives numerous fibres from the Puborectalis.

Nerve-supply.—The Sphincter ani externus is supplied by a branch from the fourth sacral nerve and by twigs from the inferior hæmorrhoidal branch (S. 2 and 3) of the pudendal nerve.

Actions.—The Sphincter ani externus is normally in a state of tonic contraction, and having no antagonistic muscle it keeps the anal canal and orifice closed. It can be put into a condition of greater contraction under the influence of the will, so as to occlude the anal aperture more firmly. Taking its fixed point at the coccyx, it helps to fix the perineal body (central point of the perineum).

2. A. The Muscles of the Urogenital Region in the Male (fig. 610)

Transversus perinei superficialis.	Ischiocavernosus.
Bulbospongiosus.	Transversus perinei profundus.
Sphincter urethræ.	

The **superficial fascia** of this region consists of a superficial, fatty, and a deeper, membranous layer.

The *fatty layer* is thick, loose, areolar in texture, and contains a variable amount of fat in its meshes. In front, it is continuous with the dartos muscle of the scrotum; behind, with the subcutaneous areolar tissue surrounding the anus; and, on each side, with the same fascia on the medial sides of the thighs. In the median plane, it is adherent to the skin and to the membranous layer of the superficial fascia.

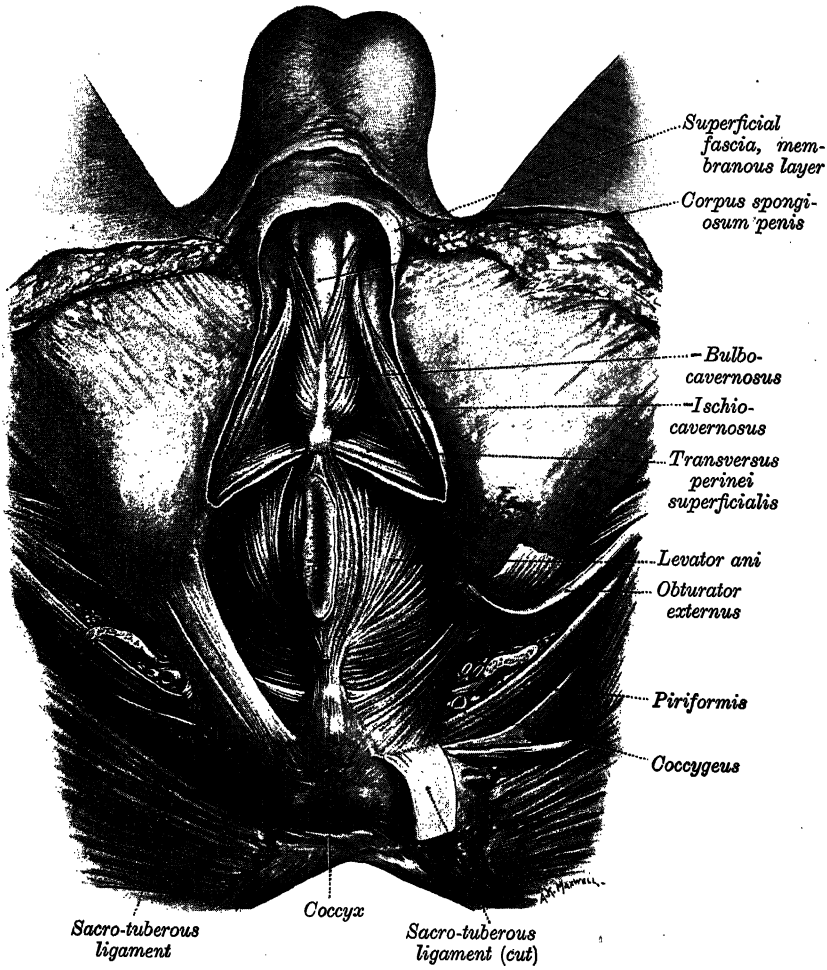
The *membranous layer of superficial fascia* (fig. 608) is thin, aponeurotic in structure, and of considerable strength, serving to bind down the muscles of the root of the penis. It is continuous, in front, with the dartos muscle, the deep fascia of the penis, and the membranous layer of the superficial fascia upon the anterior wall of the abdomen; on each side it is attached to the margins of the rami of the pubis and ischium, lateral to the crus penis and as far back as the tuberosity of the ischium; posteriorly it curves round the Transversi perinei superficiales to join the posterior margin of the perineal membrane (inferior fascia of the urogenital diaphragm) and the perineal body (central point of the perineum). In the median plane it is connected with the superficial fascia and with the median septum of the Bulbospongiosus. At its posterior part this fascia sends upwards from its deep surface a median septum, which incompletely divides the posterior portion of the subjacent space.

The *perineal body* (central tendinous point of the perineum).—This is a fibromuscular node in the median plane, about 1·25 cm. in front of the anus,

and close to the bulb of the penis (urethral bulb). Towards this point six muscles converge and are attached: viz. the Sphincter ani externus, the Bulbospongiosus, the two Transversi perinei superficiales, and the anterior fibres of the two Levatores ani. In addition, it receives longitudinal involuntary fibres from the rectal ampulla and the anal canal. It is a compact little node, and the importance of its integrity to the pelvic floor in the female has already been mentioned (p. 576).

The **Transversus perinei superficialis** is a narrow muscular slip which passes more or less transversely across the perineal space in front of the anus. It is

FIG. 610.—The muscles of the male perineum. (From Quain's *Anatomy*, XI. Edition).



often feebly developed, and is sometimes absent. It arises by tendinous fibres from the medial and anterior part of the tuberosity of the ischium, and, running medially, is inserted into the perineal body, joining in this situation with the muscle of the opposite side, with the Sphincter ani externus behind, and with the Bulbospongiosus in front. In some cases, the fibres of the deeper layer of the Sphincter ani externus decussate in front of the anus and are continued into this muscle. Occasionally it gives off fibres which join with the Bulbospongiosus of the same side.

Action.—The simultaneous contraction of the two Transversi perinei superficiales helps to fix the perineal body.

The **Bulbospongiosus** (Bulbocavernosus) is placed in the median line of the perineum, in front of the anus, and consists of two symmetrical parts, united

by a median tendinous raphe. It arises from this median raphe and from the perineal body (central tendinous point of the perineum). Its fibres diverge like the barbs of a quill-pen ; the most posterior form a thin layer, which is lost on the perineal membrane (inferior fascia of the urogenital diaphragm) ; the middle fibres encircle the bulb and the adjacent part of the corpus spongiosum penis (corpus cavernosum urethræ), and are inserted into a strong aponeurosis on the upper part of that structure ; the anterior fibres spread out over the side of the corpus cavernosum penis, to be inserted partly into that body, anterior to the Ischiocavernosus, and partly into a tendinous expansion which covers the dorsal vessels of the penis.

Actions.—The Bulbospongiosus serves to empty the canal of the urethra, after the bladder has expelled its contents ; during the greater part of the act of micturition its fibres are relaxed, and they only come into action at the end of the process. The middle fibres are supposed by Krause to assist in the erection of the corpus spongiosum penis, by compressing the erectile tissue of the bulb. The anterior fibres, according to Tyrrel, also contribute to the erection of the penis by compressing the deep dorsal vein of the penis, as their tendinous expansion is inserted into, and is continuous with, the fascia covering the dorsal vessels of the penis.

The **Ischiocavernosus** covers the crus penis. It arises by tendinous and fleshy fibres from the inner surface of the tuberosity of the ischium, behind the crus penis ; and from the ramus of the ischium on both sides of the crus. The muscular fibres end in an aponeurosis which is inserted into the sides and under surface of the crus penis.

Action.—The Ischiocavernosus compresses the crus penis, and retards the return of the blood through the veins, and thus serves to maintain the penis erect.

Between the muscles just examined a triangular space exists, bounded medially by the Bulbospongiosus, laterally by the Ischiocavernosus, and behind by the Transversus perinei superficialis ; the floor is formed by the perineal membrane (inferior fascia of the urogenital diaphragm). The scrotal vessels and nerves, and the perineal branch of the posterior femoral cutaneous nerve traverse the space from behind forwards ; the transverse perineal artery courses along its posterior boundary on the Transversus perinei superficialis.

The **deep fascia** of the urogenital region forms an investment for the Transversus perinei profundus and the Sphincter urethræ, but within it there are also the deep vessels and nerves of this part. It is stretched almost horizontally across the pubic arch, so as to close the anterior part of the pelvic outlet. It consists of two membranous laminæ (fig. 611), which are united at the free edges of the muscles. The stronger and more superficial of these laminæ is named the *perineal membrane* (inferior fascia of the urogenital diaphragm). Its base, directed backwards, is connected to the perineal body and is continuous with the anal fascia, and, behind the Transversus perinei superficialis, with the membranous layer of the superficial fascia. Its lateral margins are attached to the inferior ramus of the pubis and the ramus of the ischium, above the crus penis. Its apex, directed forwards, is thickened to form the *transverse perineal ligament* ; between this ligament and the inferior pubic ligament the deep dorsal vein of the penis (or clitoris) enters the pelvis. It is perforated, from 2 to 3 cm. below the symphysis pubis, by the urethra, the aperture for which is circular and about 6 mm. in diameter ; by the arteries and nerves to the bulb and, close to the urethra, by the ducts of the bulbo-urethral glands ; by the deep arteries of the penis, one on each side close to the pubic arch and about halfway along the attached margin of the membrane ; by the dorsal arteries and nerves of the penis near the apex of the membrane. Its base is also perforated by the scrotal vessels and nerves.

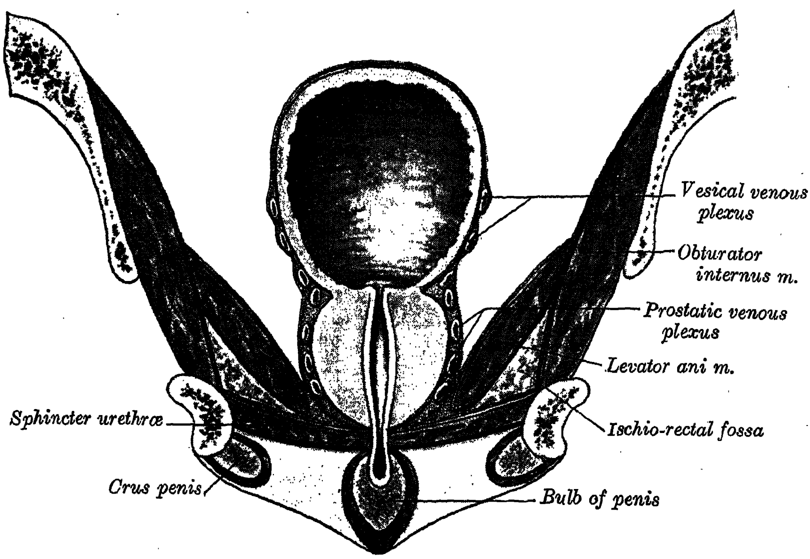
If the perineal membrane be detached the following structures will be exposed : the membranous portion of the urethra, the Transversus perinei profundus and Sphincter urethræ, the bulbo-urethral glands and their ducts, the pudendal vessels and dorsal nerves of the penis, the arteries and nerves of the bulb of the penis, and a plexus of veins.

These structures are separated from the pelvis by a second, but less definite

layer of fascia, which forms the deeper of the two laminæ of the deep fascia of the urogenital region. It is continuous with the obturator fascia and stretches across the pubic arch. If the obturator fascia be traced medially after leaving the Obturator internus muscle, it will be found attached by some of its anterior fibres to the inner margin of the pubic arch, while its posterior fibres pass over this attachment to become continuous with the fascia on the deep surface of the Sphincter urethræ and the Transversus perinei profundus. Behind, this layer of the fascia blends with the perineal membrane, the perineal body and the membranous layer of the superficial fascia; above, at the point where it is pierced by the urethra, it becomes continuous with the fascial sheath of the prostate.

The **Transversus perinei profundus** * arises from the rami of the ischium and runs to the median plane, where it interlaces in a tendinous raphe with its fellow of the opposite side. It lies in the same plane as the Sphincter urethræ; formerly the two muscles were described together as the *Constrictor* or *Compressor urethræ*.

FIG. 611.—A coronal section through the anterior part of the pelvis. Anterior aspect. Diagrammatic.



Action.—The Transversus perinei profundus is a tensor of the perineal body (central point of the perineum).

The **Sphincter urethræ** surrounds the membranous portion of the urethra, and lies between the two layers of the deep fascia of the urogenital region. Its *external* fibres arise from the junction of the rami of the pubis and ischium, to the extent of 1·25 or 2 cm., and from the neighbouring fasciæ. They arch across the front of the urethra and bulbo-urethral glands, pass round the urethra, and behind it unite with the muscle of the opposite side, by means of a tendinous raphe. Its *innermost* fibres form a continuous circular investment for the membranous urethra.

Actions.—The muscles of both sides act together as a sphincter, compressing the membranous portion of the urethra. During micturition they, like the Bulbospongiosus, are relaxed, and only come into action at the end of the process to eject the last drops of urine.

Nerve-supply.—All the muscles of the urogenital region are supplied by the perineal branch of the pudendal nerve (S. 2, 3 and 4).

* In the B.N.A. the Transversus perinei profundus and the Sphincter urethræ are included under the term 'urogenital diaphragm.'

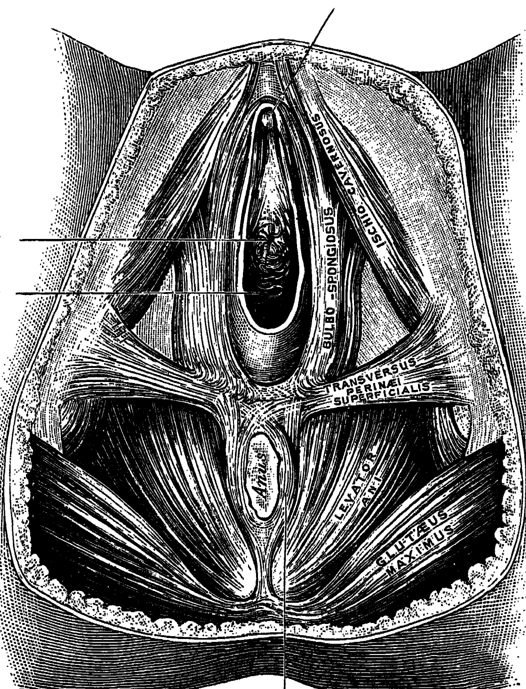
2. B. The Muscles of the Urogenital Region in the Female (fig. 612)

Transversus perinei superficialis. Ischiocavernosus.
Bulbospongiosus. Transversus perinei profundus.
Sphincter urethræ.

The **Transversus perinei superficialis** in the female is a narrow muscular slip, which differs but little from the corresponding muscle in the male (p. 578).

The **Bulbospongiosus** (Bulbocavernosus) surrounds the orifice of the vagina. It covers the lateral parts of the vestibular bulbs, and is attached posteriorly to the perineal body (central tendinous point of the perineum), where it blends with the Sphincter ani externus. Its fibres pass forwards on each side of the vagina, to be inserted into the corpora cavernosa clitoridis ; a fasciculus crosses over the body of the clitoris so as to compress the deep dorsal vein.

Fig. 612.—The muscles of the female perineum. (Modified from a drawing by Peter Thompson.)



Actions.—The Bulbospongiosus diminishes the orifice of the vagina. The anterior fibres contribute to the erection of the clitoris by the compression of its deep dorsal vein.

The **Ischiocavernosus**, smaller than the corresponding muscle in the male, covers the unattached surface of the crus clitoridis. It arises by tendinous and fleshy fibres from the inner surface of the tuberosity of the ischium, behind the crus clitoridis ; and from the adjacent portion of the ramus of the ischium. The muscular fibres end in an aponeurosis which is inserted into the sides and under surface of the crus clitoridis.

Actions.—The Ischiocavernosus compresses the crus clitoridis and retards the return of blood through the veins, and thus serves to maintain the clitoris erect.

The *perineal membrane* (inferior fascia of the urogenital diaphragm) in the female is weaker than that in the male, and is pierced by the aperture of the

vagina, with the external coat of which it blends. It covers the following structures: portions of the urethra and the vagina, the Transversus perinei profundus and Sphincter urethræ muscles, the greater vestibular glands and their ducts, the internal pudendal vessels, the dorsal nerves of the clitoris, the arteries and nerves of the vestibular bulbs, and a plexus of veins.

The **Transversus perinei profundus** arises from the ramus of the ischium and runs across behind the vagina to meet the corresponding muscle of the opposite side. The more anterior fibres become lost in the vaginal wall.

Action.—The Transversus perinei profundus helps to fix the perineal body (central tendinous point of the perineum).

The **Sphincter urethræ**, like the corresponding muscle in the male, consists of external and internal fibres. The *external* fibres arise on either side from the margin of the inferior ramus of the pubis. They are directed across the pubic arch in front of the urethra, and pass round it to blend with the muscular fibres of the opposite side, between the urethra and vagina. The *innermost* fibres encircle the lower end of the urethra.

Actions.—The muscles of the two sides act as a constrictor of the urethra.

THE FASCIÆ AND MUSCLES OF THE UPPER LIMB

The muscles of the upper limb are divisible into the following groups:

I. Muscles connecting the upper limb with the vertebral column.
II. Muscles connecting the upper limb with the anterior and lateral thoracic walls.
III. Muscles of the shoulder.
IV. Muscles of the upper arm.
V. Muscles of the forearm.
VI. Muscles of the hand.

I. The Muscles connecting the Upper Limb with the Vertebral Column

Trapezius.
Latissimus dorsi.
Rhomboideus major.
Rhomboideus minor.
Levator scapulæ.

The **superficial fascia** of the back forms a layer of considerable thickness and strength, and contains a quantity of granular fat. It is continuous with the general superficial fascia.

The **deep fascia** is a dense fibrous layer, attached above to the superior nuchal line of the occipital bone; in the median plane it is fixed to the ligamentum nuchæ and supraspinous ligament, and to the spines of all the vertebræ below the seventh cervical; laterally, in the neck it is continuous with the deep cervical fascia; over the shoulder it is attached to the spine and acromion of the scapula, and is continued downwards over the Deltoid to the arm; on the thorax it is continuous with the deep fascia of the axilla and chest, and on the abdomen with that covering the abdominal muscles; below, it is attached to the crest of the ilium.

The **Trapezius** (fig. 613) is a flat, triangular muscle, covering the back of the neck and shoulder. It arises from the medial one-third of the superior nuchal line of the occipital bone, the external occipital protuberance, the ligamentum nuchæ, the spine of the seventh cervical, and the spines of all the thoracic vertebræ, and the corresponding portion of the supraspinous ligament. The superior fibres proceed downwards and laterally, the inferior upwards and laterally, and the middle horizontally; the superior fibres are inserted into the posterior border of the lateral one-third of the clavicle; the middle fibres into the medial margin of the acromion and the superior lip of the crest of the spine of the scapula; the inferior fibres converge and end in an aponeurosis, which glides over the smooth triangular surface at the medial end of the spine of the scapula and is inserted into a tubercle at the apex of this smooth triangular surface. The upper part of the Trapezius is connected to the occipital bone by a thin fibrous lamina, firmly adherent to the skin; the middle part arises by a

broad semi-elliptical aponeurosis, which reaches from the sixth cervical to the third thoracic vertebra ; the lower part arises by short tendinous fibres. The two Trapezius muscles together resemble a trapezium, or quadrangle ; two angles corresponding to the shoulders ; a third to the occipital protuberance ; and the fourth to the spine of the twelfth thoracic vertebra.*

The clavicular insertion of this muscle varies in extent ; it sometimes reaches as far as the middle of the clavicle, and occasionally blends with the posterior edge of the Sternomastoid.

Nerve-supply.—The Trapezius is supplied by the accessory nerve and by branches from the third and fourth cervical nerves.

Actions.—When the head is fixed, the Trapezius acting with the Levator scapulæ elevates the scapula and with it the point of the shoulder ; acting with the Serratus anterior, the Trapezius rotates the scapula in a forward direction so that the arm can be raised above the head ; acting with the Rhomboids, the Trapezius retracts the scapula and so braces back the shoulder. When the shoulder is fixed, the Trapezius draws the head backwards and laterally.

The tonus of the Trapezius muscles is responsible for maintaining the level and poise of the shoulders ; when it is impaired, drooping of the shoulders is an obvious feature.

The **Latissimus dorsi** (fig. 613) is a large, triangular, flat muscle, which covers the lumbar region and the lower one-half of the thoracic region ; but its fibres converge to a narrow tendon of insertion. It arises by tendinous fibres from the spines of the lower six thoracic vertebræ under cover of the Trapezius, and from the posterior layer of the lumbar fascia (p. 546), by which it is attached to the spines of the lumbar and sacral vertebræ, to the supraspinous ligament, and to the posterior part of the crest of the ilium. In addition, it arises by muscular fibres from the posterior part of the outer lip of the crest of the ilium, lateral to the margin of the Sacrospinalis, and by fleshy slips from the three or four lower ribs ; the latter interdigitate with the lower digitations of the Obliquus abdominis externus (fig. 595). From this extensive origin the fibres pass in different directions, the upper ones horizontally, the middle obliquely upwards, and the lower almost vertically upwards, so as to converge and form a thick fasciculus, the upper part of which crosses, and usually receives a few fibres from, the inferior angle of the scapula. The muscle curves around the lower border of the Teres major, and is twisted upon itself, so that the superior fibres become at first posterior and then inferior, and the ascending fibres at first anterior and then superior. It ends in a quadrilateral tendon, about 7 cm. long, which passes in front of the tendon of the Teres major, and is inserted into the bottom of the bicipital groove (intertubercular sulcus) of the humerus, giving an expansion to the deep fascia of the upper arm ; its insertion extends higher on the humerus than that of the tendon of the Pectoralis major. The lower border of its tendon is united with that of the Teres major, the surfaces of the two tendons being separated near their insertions by a bursa ; another bursa is sometimes interposed between the muscle and the inferior angle of the scapula.

A muscular slip, named the *axillary arch*, varying from 7 to 10 cm. in length, and from 5 to 15 mm. in breadth, occasionally springs from the upper edge of the Latissimus dorsi about the middle of the posterior fold of the axilla, and crosses the axilla in front of the axillary vessels and nerves, to join the under surface of the tendon of the Pectoralis major, the Coracobrachialis, or the fascia over the Biceps. This axillary arch crosses the axillary artery, just above the spot usually selected for the application of a ligature, and may mislead the surgeon during the operation. It is present in about seven per cent. of subjects and may be recognised easily by the direction of its fibres.

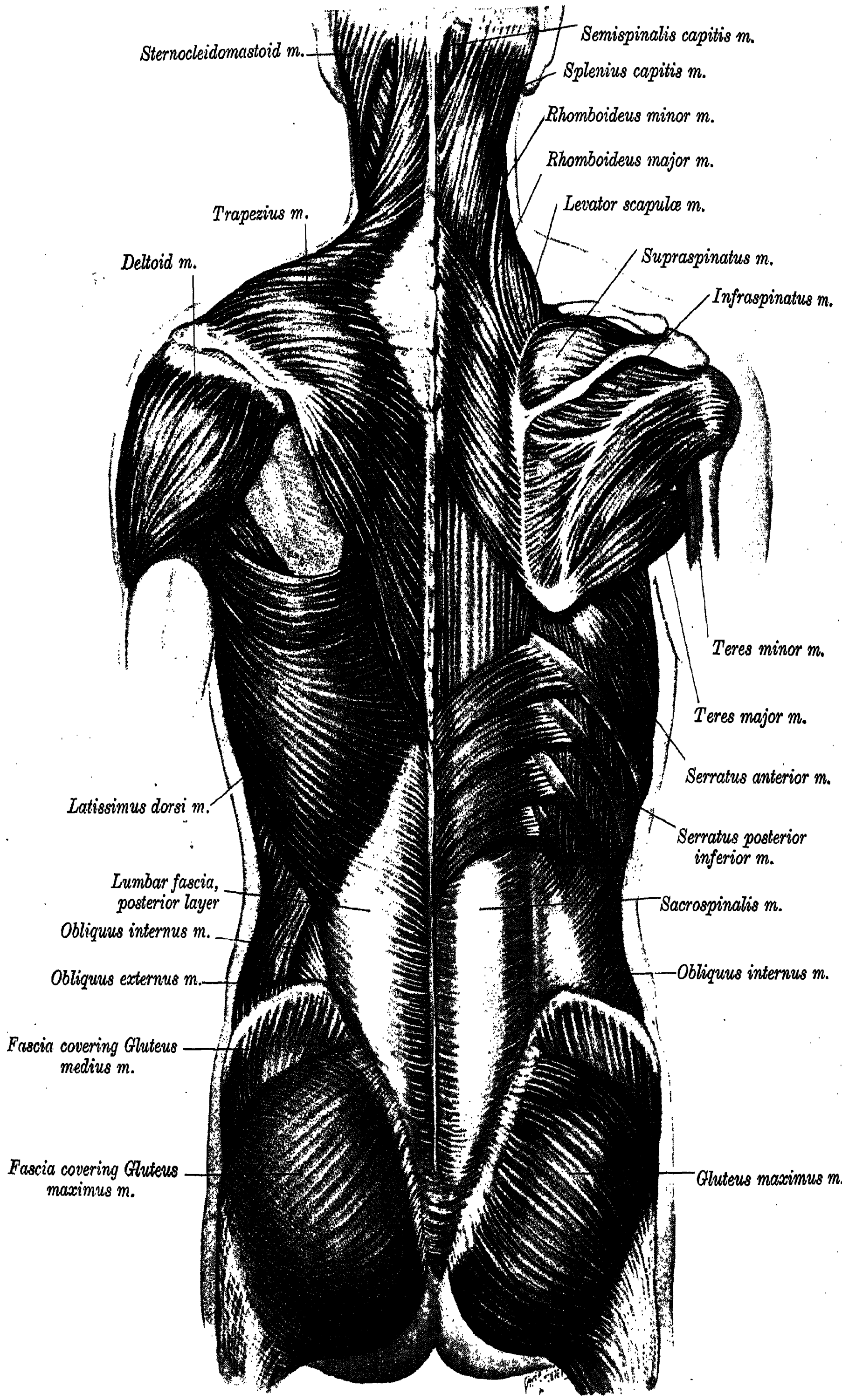
A fibrous slip usually passes from the lower border of the tendon of the Latissimus dorsi, near its insertion, to the long head of the Triceps. This is occasionally muscular, and is the representative of the *dorso-epitrochlearis brachii* of apes.

Nerve-supply.—The *nerve to Latissimus dorsi* (thoracodorsal nerve) is derived from the posterior cord of the brachial plexus (C. 6, 7 and 8).

Actions.—The Latissimus dorsi depresses and adducts the humerus, draws it backwards, and rotates it medially. When both arms are fixed it helps to

* The two muscles cover the back of the neck and shoulders like a monk's cowl, and therefore the Trapezius is sometimes termed the *Musculus cucullaris*.

FIG. 613.—The muscles connecting the upper limb with the vertebral column.



N.B.—On the right side, the Sternomastoid, Trapezius, Latissimus dorsi, Deltoid and Obliquus externus abdominis muscles have been removed.

pull the trunk upwards and forwards as in climbing. In addition, it takes part in violent expiratory efforts, such as coughing. The pressure exerted by the tonus of the muscle on the inferior angle of the scapula keeps it in contact with the chest-wall, more especially when the arm is elevated, as that movement puts the fibres of the muscle on the stretch.

The lower part of the lateral margin of the Latissimus dorsi is separated from the posterior free border of the External oblique muscle by a small triangular interval, named the *lumbar triangle*, the base of which is formed by the iliac crest, and the floor by the Internal oblique muscle (fig. 613). Another triangle, sometimes termed the *triangle of auscultation*, is situated behind the scapula. It is bounded above by the Trapezius, below by the Latissimus dorsi, and laterally by the medial border of the scapula; the floor is partly formed by the Rhomboideus major. If the scapula be drawn forwards by folding the arms across the chest, and the trunk bent forwards, parts of the sixth and seventh ribs and the interspace between them become subcutaneous and available for auscultation of the lung.

The **Rhomboideus major** (fig. 613) arises by tendinous fibres from the spines of the second, third, fourth, and fifth thoracic vertebræ and the supraspinous ligament. The fibres of the muscle are directed downwards and laterally and are inserted into the medial border (vertebral border) of the scapula between the triangular surface of the root of the spine and the inferior angle. Usually the insertion is an indirect one, the muscular fibres ending in a tendinous band which is fixed at its ends to the two points mentioned and joined to the medial border by a thin membrane; occasionally the arch is incomplete, and some of the muscular fibres are then inserted directly into the scapula.

The **Rhomboideus minor** (fig. 613) arises from the lower part of the ligamentum nuchæ and from the spines of the seventh cervical and first thoracic vertebræ; it is inserted into the base of the triangular smooth surface at the apex of the spine of the scapula. It is usually separated from the Rhomboideus major by a slight interval, but the adjacent margins of the two muscles are occasionally united.

Nerve-supply.—The *nerve to the Rhomboid muscles* arises from the anterior primary ramus of the fifth cervical nerve in the substance of the Scalenus medius muscle.

Action.—The Rhomboid muscles, acting with the Trapezius, retract the scapula and brace back the shoulder; acting with the Levator scapulæ and Pectoralis minor, they rotate the scapula so as to depress the point of the shoulder.

The **Levator scapulæ** (figs. 588, 613) is situated at the back and side of the neck. It arises by tendinous slips from the transverse processes of the atlas and axis and from the posterior tubercles of the transverse processes of the third and fourth cervical vertebræ. It is inserted into the medial border of the scapula, between the superior angle and the triangular smooth surface at the apex of the spine.

Nerve-supply.—The Levator scapulæ is supplied directly by branches from the third and fourth cervical nerves, and by a branch from the nerve to the Rhomboids (C. 5).

Actions.—If the cervical part of the vertebral column is fixed, the Levator scapulæ may act with the Trapezius to elevate the scapula, or to sustain a weight carried on the shoulder; or it may act with the Rhomboids and Pectoralis minor to rotate the scapula so as to depress the point of the shoulder. If the shoulder is fixed, the muscle inclines the neck to the same side.

II. The Muscles connecting the Upper Limb with the Anterior and Lateral Thoracic Walls

Pectoralis major.	Subclavius.
Pectoralis minor.	Serratus anterior.

The **superficial fascia** of the anterior thoracic region is continuous with that of the neck and upper limb above, and of the abdomen below. It encloses the mammary gland and gives off numerous septa which pass into it to support

its various lobes. From the fascia over the front of the gland, fibrous processes pass forwards to the integument and nipple; these were called by Sir Astley Cooper the *ligamenta suspensoria.*

The **pectoral fascia** is a thin lamina, covering the surface of the Pectoralis major and sending numerous prolongations between its fasciculi; it is attached in the median plane to the front of the sternum; above, to the clavicle; laterally and below, it is continuous with the fascia of the shoulder, axilla and thorax. It is very thin over the upper part of the Pectoralis major, but thicker in the interval between it and the Latissimus dorsi, where it forms the floor of the axillary space and is named the *axillary fascia*; this divides at the lateral margin of the Latissimus dorsi into two layers, which ensheathe this muscle and are attached behind to the spines of the thoracic vertebræ. As the fascia leaves the lower edge of the Pectoralis major to cross the floor of the axilla, it sends a layer upwards under cover of the muscle; this lamina splits to envelop the Pectoralis minor, and at the upper edge of this muscle is continuous with the clavipectoral fascia (coracoclavicular fascia) (p. 588). The hollow of the armpit, seen when the arm is abducted, is produced mainly by the traction of this fascia on the axillary floor, and hence the lamina is sometimes named the *suspensory ligament* of the axilla. At the lower part of the thoracic region the deep fascia is well developed, and is continuous with the fibrous sheath of the Rectus abdominis.

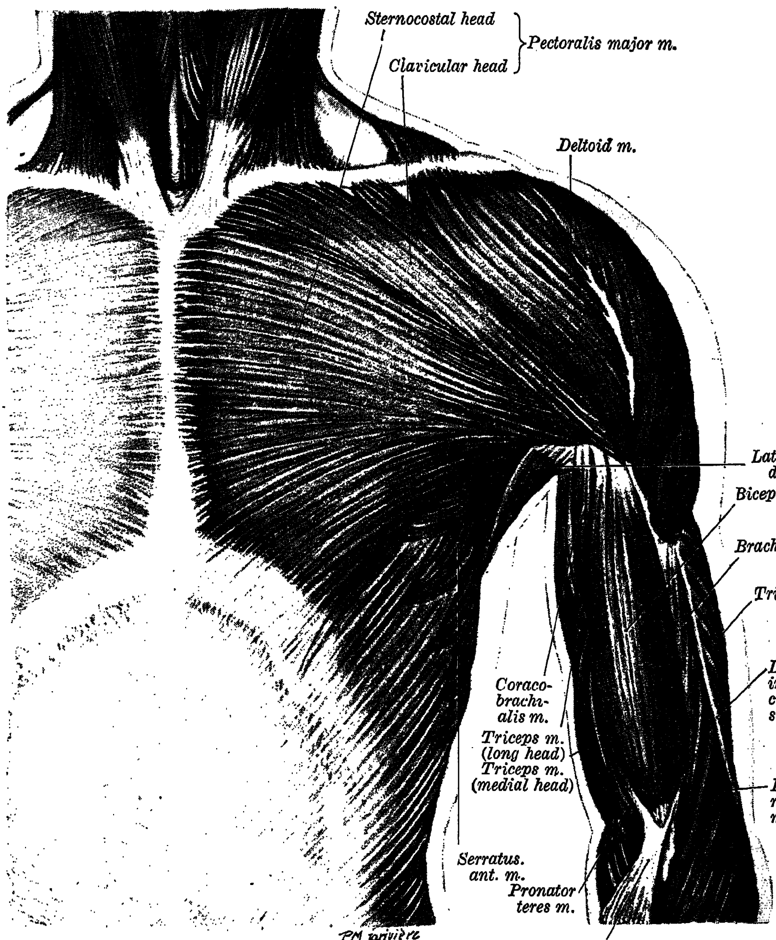
Applied Anatomy.—In cases of suppuration in the axilla, the pus is prevented from extending downwards by the axillary fascia, and therefore tends to spread upwards, behind the pectoral muscles, towards the root of the neck. Early evacuation of the pus is therefore necessary. The incision should be made midway between the anterior and posterior axillary folds, so as to avoid the lateral thoracic and subscapular vessels, and the edge of the knife should be directed away from the axillary vessels.

The **Pectoralis major** (fig. 614) is a thick, triangular muscle situated at the upper and front part of the chest. It arises from the anterior surface of the sternal half of the clavicle: from half the breadth of the anterior surface of the sternum, as low down as the attachment of the cartilage of the sixth or seventh rib: from the cartilages of all the true ribs, with the exception, frequently, of the first, or seventh, or both, and from the aponeurosis of the Obliquus externus abdominis. From this extensive origin the fibres converge towards their insertion; those arising from the clavicle pass obliquely downwards and laterally, and are usually separated from the rest by a slight interval; those from the lower part of the sternum, and the cartilages of the lower true ribs, run upwards and laterally; while the middle fibres pass horizontally. They all end in a flat tendon, about 5 cm. broad, which is inserted into the lateral lip of the bicipital groove (intertubercular sulcus) of the humerus. This tendon consists of two laminæ, placed one in front of the other, and usually blended together below. The anterior lamina, the thicker, receives the clavicular and the uppermost sternal fibres; they are inserted in the same order as that in which they arise: that is to say, the most lateral of the clavicular fibres are inserted at the upper part of the anterior lamina, and the uppermost sternal fibres to the lower part of the lamina, which extends as low as the tendon of the Deltoid muscle and joins with it. The posterior lamina of the tendon receives the attachment of the greater part of the sternal portion and the deep fibres, i.e. those from the costal cartilages. These deep fibres, and particularly those from the lower costal cartilages, turn backwards successively behind the superficial and upper ones and reach a higher level. As a result, the tendon appears to be twisted. The posterior lamina of the tendon reaches higher on the humerus than the anterior, and gives off an expansion which covers the bicipital groove and blends with the capsular ligament of the shoulder-joint. From the deepest fibres of this lamina at its insertion an expansion is given off which lines the bicipital groove, while from the lower border of the tendon a third expansion passes downwards to the fascia of the upper arm.

Relations.—*In front,* the Pectoralis major is related to the skin, superficial fascia, Platysma, medial and intermediate supraclavicular nerves, mammary gland, and deep fascia; its *posterior surface* is in contact with the sternum, ribs and costal cartilages, clavipectoral fascia, Subclavius, Pectoralis minor, Serratus anterior, and Intercostal muscles;

it forms the superficial stratum of the anterior wall of the axillary space, and so covers the axillary vessels and nerves and the upper parts of the Biceps and Coracobrachialis. Its *upper border* is separated from the Deltoid muscle by a slight interspace (*the infraclavicular fossa*), in which the cephalic vein and deltoid branch of the acromiothoracic (thoraco-acromial) artery lie. Its *lower border* forms the anterior fold of the axilla; it is separated from the Latissimus dorsi by a considerable interval at the medial wall of the axilla, but the two muscles gradually converge towards the lateral wall of the space.

FIG. 614.—The superficial muscles of the front of the chest and upper arm. Left side.



Nerve-supply.—The Pectoralis major is supplied by the lateral and medial pectoral nerves (lateral and medial anterior thoracic nerves); through these it receives filaments from all the nerves entering into the formation of the brachial plexus; the fibres for the clavicular part of the muscle are derived from C. *5* * and 6.

Actions.—The Pectoralis major adducts the arm and rotates it medially. When the arm is extended, i.e. drawn backwards and laterally, the Pectoralis major draws it forwards and medially. The two heads of the muscle work together in effecting these movements. When the arm is flexed, the sterno-

* Throughout the remainder of this section the use of italics for numerals denoting spinal nerves indicates that it is doubtful whether the nerve italicised contributes to the motor innervation of the muscle.

costal fibres take no part in the movement, which is carried out by the clavicular head (*portio attollens*) acting with the anterior fibres of the Deltoid muscle and the Coracobrachialis. When the opposite movement, usually carried out with the assistance of the force of gravitation, is resisted, the sternocostal head (*portio deprimens*) alone helps the Latissimus dorsi and Teres major to depress the arm. When the arms are fixed, the sternocostal fibres draw the trunk upwards and forwards as in climbing.

The **clavipectoral fascia** (coracoclavicular fascia) is a strong fascia situated under cover of the clavicular portion of the Pectoralis major. It occupies the interval between the Pectoralis minor and Subclavius, and protects the axillary vessels and nerves. Traced upwards, it splits to enclose the Subclavius, and is attached to the clavicle, in front of and behind the muscle: the layer behind the muscle fuses with the deep cervical fascia and with the sheath of the axillary vessels. Medially, the clavipectoral fascia blends with the fascia covering the first two intercostal spaces, and is attached also to the first rib medial to the origin of the Subclavius. Laterally, it is thick and dense, and is attached to the coracoid process, blending with the coracoclavicular ligament. The portion extending from the first rib to the coracoid process is often stronger than the rest, and is sometimes called the *costocoracoid ligament*. Below this, the fascia is thin; it splits to ensheathe the Pectoralis minor; and from the lower border of this muscle it is continued downwards to join the axillary fascia, and laterally to unite with the fascia covering the short head of the Biceps. The clavipectoral fascia is pierced by the cephalic vein, acromiothoracic artery and vein, and lateral pectoral (anterior thoracic) nerve.

The **Pectoralis minor** (fig. 615) is a thin, triangular muscle, situated at the upper part of the thorax, deep to the Pectoralis major. It arises from the upper margins and outer surfaces of the third, fourth and fifth ribs (frequently the second, third and fourth ribs) near their cartilages, and from the aponeuroses covering the External intercostal muscles; the fibres pass upwards and laterally, and converge to form a flat tendon, which is inserted into the medial border and upper surface of the coracoid process of the scapula. Sometimes a part or the whole of the tendon is continued over the coracoid process and through the coraco-acromial ligament; when this occurs the tendon blends with the coracohumeral ligament and thus gains an attachment to the humerus.

Relations.—Its *anterior surface* is in relation with the Pectoralis major, the lateral pectoral (anterior thoracic) nerve and the pectoral branches of the acromiothoracic artery; its *posterior surface*, with the ribs, External intercostal muscles, Serratus anterior, the axillary space, and the axillary vessels and brachial plexus of nerves. Its *upper border* is separated from the clavicle by a narrow triangular interval occupied by the clavipectoral fascia, behind which are the axillary vessels and nerves. Running parallel with the *lower border* of the muscle is the lateral thoracic artery; piercing and partly supplying the muscle is the medial pectoral (anterior thoracic) nerve.

Nerve-supply.—The Pectoralis minor is supplied by both the pectoral (anterior thoracic) nerves (C. 7 and 8, and T. *1*).

Actions.—The Pectoralis minor assists the Serratus anterior to draw the scapula forwards round the chest wall. Acting with the Levator scapulæ and the Rhomboids, the Pectoralis minor rotates the scapula so as to depress the point of the shoulder. When the arm is fixed, it assists in elevating the ribs in forced inspiration.

The **Subclavius** (fig. 615) is a small, triangular muscle, placed between the clavicle and first rib. It arises by a short, thick tendon from the junction of the first rib and first costal cartilage, in front of the costoclavicular ligament; the fleshy fibres proceed obliquely upwards and laterally, to be inserted into the groove on the under surface of the intermediate third of the clavicle.

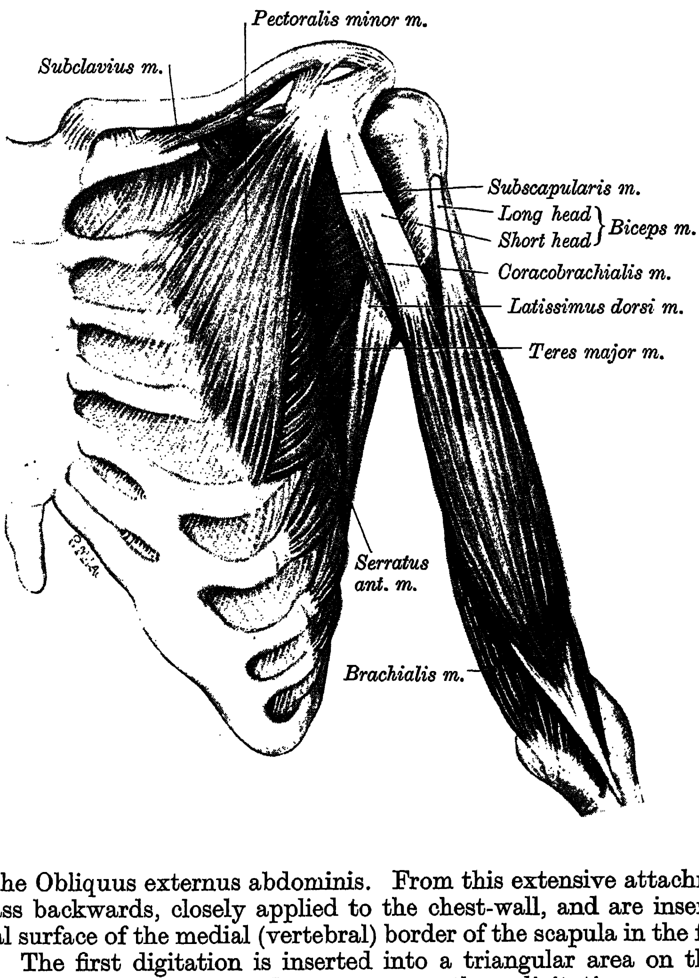
Relations.—Its *posterior surface* is separated from the first rib by the subclavian vessels and brachial plexus of nerves. Its *anterior surface* is separated from the Pectoralis major by the clavipectoral fascia, which, with the clavicle, forms an osseofibrous sheath for the muscle.

Nerve-supply.—The Subclavius is supplied by a branch which derives its fibres from C. 5 and *6*.

Action.—The Subclavius pulls the point of the shoulder downwards and forwards and steadies the clavicle, during movements of the shoulder, by bracing it against the articular disc of the sternoclavicular joint.

The **Serratus anterior** (fig. 615) is a muscular sheet, situated between the ribs and scapula at the upper and lateral parts of the chest. It arises by fleshy slips or digitations from the outer surfaces and superior borders of the upper eight or nine ribs, and from the aponeuroses covering the intervening Intercostal muscles. Each digitation arises from the corresponding rib, but the first springs in addition from the second rib, and from the fascia covering the first intercostal space. The lower four slips interdigitate with the upper five

FIG. 615.—The deep muscles of the front of the chest and arm. Left side.



slips of the Obliquus externus abdominis. From this extensive attachment the fibres pass backwards, closely applied to the chest-wall, and are inserted into the costal surface of the medial (vertebral) border of the scapula in the following manner. The first digitation is inserted into a triangular area on the costal surface of the superior angle. The next two or three digitations spread out to form a thin, triangular sheet, the base of which is directed backwards and is inserted into nearly the whole length of the costal surface of the medial border. The lower four or five digitations converge to form a fan-shaped mass, the apex of which is inserted, by muscular and tendinous fibres, into a triangular impression on the costal surface of the inferior angle.

Nerve-supply.—The nerve to Serratus anterior arises by three roots from the fifth, sixth and seventh cervical nerves (anterior primary rami) close to the intervertebral foramina and descends on the outer surface of the muscle.

Actions.—The Serratus anterior, acting with the Pectoralis minor, draws the scapula forwards, and is the chief muscle concerned in all pushing and

punching movements. Its lower and stronger fibres move the lower angle of the scapula forwards and assist the Trapezius in rotating the bone at the acromioclavicular joint, and thus aid this muscle in raising the arm above the head. It is also an assistant to the Deltoid in raising the arm, inasmuch as during the action of this latter muscle it helps the other muscles inserted into the scapula to steady the bone and so enables the Deltoid to exert its action on the humerus only. While the Deltoid is raising the arm to a right angle with the scapula, the Serratus anterior and the Trapezius are rotating the scapula, and the arm can be raised above the head as the result of this combination of movements. When the scapula is fixed, the lower part of the muscle will pull upon the ribs, and act as a muscle of inspiration.

Applied Anatomy.—When the Serratus anterior is paralysed, the medial (vertebral) border, and especially the lower angle of the scapula, leave the ribs and stand out prominently on the surface, giving a peculiar 'winged' appearance to the back. The patient is unable to raise the arm or to carry out pushing movements, and attempts to do so are followed by a further projection of the lower angle of the scapula from the back of the thorax.

III. The Muscles of the Shoulder

Deltoideus.	Infraspinatus.
Subscapularis.	Teres minor.
Supraspinatus.	Teres major.

The **deep fascia** covering the Deltoid invests the muscle, and sends numerous septa between the fasciculi. In front, it is continuous with the pectoral fascia; behind, where it is thick and strong, with the fascia infraspinata; above, it is attached to the clavicle, the acromion, and the crest of the spine of the scapula; below, it is continuous with the brachial fascia.

The **Deltoid** (fig. 614) is a thick, triangular muscle, which covers the shoulder-joint. It arises from the anterior border and upper surface of the lateral one-third of the clavicle; from the lateral margin and upper surface of the acromion, and from the lower lip of the crest of the spine of the scapula, as far back as the triangular surface at its medial end. The fibres converge towards their insertion, the middle passing vertically, the anterior inclining backwards, and the posterior forwards; they unite in a thick tendon which is inserted into the deltoid tuberosity on the lateral side of the shaft of the humerus. At its insertion the tendon gives off an expansion to the deep fascia of the upper arm. This muscle is remarkably coarse in texture, and the part arising from the acromion consists of oblique fibres; these arise in a bipennate manner from the sides of tendinous septa, generally four in number, which pass downwards from the acromion into the muscle. These oblique fibres are inserted into similar tendinous septa, generally three in number, which ascend from the tendon of insertion of the muscle and alternate with the descending septa. The portions of the muscle arising from the clavicle and spine of the scapula are not arranged in this manner, but are inserted into the margins of the inferior tendon.

Relations.—Its *superficial surface* is in relation with the skin, the superficial and deep fasciæ, Platysma, lateral supraclavicular and upper lateral brachial cutaneous nerves. Its *deep surface* covers the coracoid process, coraco-acromial ligament, subacromial bursa, Pectoralis minor, Coracobrachialis, both heads of the Biceps, the tendon of the Pectoralis major, the insertions of the Subscapularis, Supraspinatus, Infraspinatus, and Teres minor, the long and lateral heads of the Triceps, the circumflex humeral vessels, the circumflex (axillary) nerve and the surgical neck and upper part of the shaft of the humerus. Its *anterior border* is separated at its upper part from the Pectoralis major by the infraclavicular fossa, in which the cephalic vein and deltoid branch of the acromiothoracic artery lie; lower down the two muscles are in contact. Its *posterior border* rests on the Infraspinatus and Triceps. As the middle fibres pass from their origin to their insertion they curve over the bony prominence of the greater tuberosity of the humerus and this relationship determines the rounded contour of the normal shoulder.

Nerves.—The Deltoid muscle is supplied by the circumflex (axillary) nerve (C. 5 and *6*).

Actions.—The muscle is capable of acting in parts or as a whole. The anterior fibres cooperate with the Pectoralis major in drawing the arm forwards, and they can act as medial rotators of the humerus. The posterior fibres cooperate

with the Latissimus dorsi and the Teres major in drawing the arm backwards and they can act as lateral rotators of the humerus. The multipennate, acromial part is the strongest and most important part of the muscle. Aided by the Supraspinatus it raises the arm from the side so as to bring it at right angles with the trunk, *while retaining the humerus in the same plane as the body of the scapula.* This point is of importance because it is only when the humerus lies in the scapular plane that scapular rotation can have its full effect in raising the arm above the head. When the arm is actively maintained in the position of true abduction (p. 460, footnote), the acromial fibres are strongly contracted, but the clavicular and posterior fibres are put on the stretch and function as stays to steady the limb.

Applied Anatomy.—The Deltoid atrophies after injury to the circumflex nerve, and in this condition dislocation of the shoulder-joint is simulated, as there is flattening of the shoulder and apparent prominence of the acromion; the distance between the acromion and the head of the bone is increased also, and the tips of the fingers can be inserted between them.

The **subscapular fascia** is a thin membrane attached to the entire circumference of the subscapular fossa, and giving origin by its deep surface to some of the fibres of the Subscapularis.

The **Subscapularis** (fig. 615) is a large, triangular muscle, which fills the subscapular fossa and arises from its medial two-thirds, including the grooved area adjoining the lateral (axillary) border of the scapula. Some fibres arise from tendinous laminæ which intersect the muscle and are attached to ridges on the bone; others from an aponeurosis which separates the muscle from the Teres major and the long head of the Triceps. The fibres pass laterally, and, gradually converging, end in a tendon which is inserted into the lesser tuberosity of the humerus and the front of the capsular ligament of the shoulder-joint. The tendon of the muscle is separated from the neck of the scapula by a large bursa, which communicates with the cavity of the shoulder-joint through an aperture in the capsular ligament.

Relations.—The *anterior surface* of this muscle forms a considerable part of the posterior wall of the axilla. Its lower and medial two-thirds are in apposition with the Serratus anterior, and its upper and lateral portion is related to the Coracobrachialis and Biceps, the axillary vessels and brachial plexus of nerves, and the subscapular vessels and nerves. Its *posterior surface* is in relation with the scapula and the capsule of the shoulder-joint. Its *lower border* is in contact with the Teres major and Latissimus dorsi.

Nerves.—The Subscapularis is supplied by the upper and lower subscapular nerves (C. *5* and 6).

Actions.—The Subscapularis rotates the head of the humerus medially; when the arm is raised, it draws the humerus forwards and downwards. It is a powerful defence to the front of the shoulder-joint.

The **fascia supraspinata** completes the osseofibrous case in which the Supraspinatus muscle is contained, and its deep surface gives origin to some of the fibres of the muscle. It is thick medially, but thinner laterally under the coraco-acromial ligament.

The **Supraspinatus** (fig. 616) occupies the supraspinous fossa, arising from its medial two-thirds, and from the fascia supraspinata. The muscular fibres pass under the acromion, and converge to a tendon which crosses the upper part of the shoulder-joint and is inserted into the highest of the three impressions on the greater tuberosity of the humerus; the tendon is intimately adherent to the capsule of the shoulder-joint.

Nerve-supply.—The Supraspinatus is supplied by the suprascapular nerve (C. 5 and *6*).

Action.—The Supraspinatus abducts the arm.

The **fascia infraspinata** covers the Infraspinatus muscle, and is fixed to the circumference of the infraspinous fossa; its deep surface gives origin to some fibres of that muscle. It is attached to the deltoid fascia along the overlapping border of the Deltoid.

The **Infraspinatus** (fig. 616) is a thick triangular muscle, which occupies the chief part of the infraspinous fossa; it arises by fleshy fibres from the medial two-thirds of the fossa, and by tendinous fibres from the ridges on its surface: it also arises from the fascia infraspinata, which covers it and separates it from the Teres major and minor muscles. The fibres converge to a tendon, which

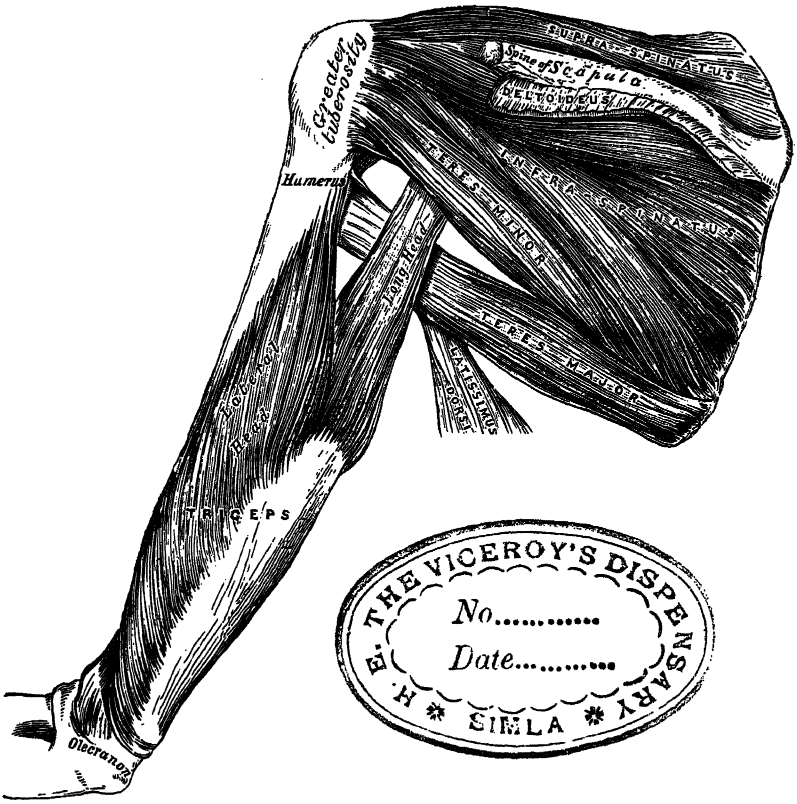
glides over the lateral border of the spine of the scapula, and, passing across the posterior part of the capsule of the shoulder-joint, is inserted into the middle impression on the greater tuberosity of the humerus. The tendon of this muscle is sometimes separated from the capsule of the shoulder-joint by a bursa which may communicate with the joint-cavity.

Nerve-supply.—The Infraspinatus is supplied by the suprascapular nerve (C. 5 and *6*).

Action.—The Infraspinatus rotates the arm laterally.

The **Teres minor** (fig. 616) is a narrow, elongated muscle, which arises from the upper two-thirds of a flattened strip on the lateral part of the dorsal surface

FIG. 616.—The muscles on the dorsum of the scapula, and the Triceps. Left side.



of the scapula, immediately adjoining the lateral (axillary) border, and from two aponeurotic laminæ, of which one separates it from the Infraspinatus, and the other from the Teres major. Its fibres run obliquely upwards and laterally; the upper ones end in a tendon which is inserted into the lowest of the three impressions on the greater tuberosity of the humerus; the lower fibres are inserted directly into the humerus immediately below this impression and just above the origin of the lateral head of the Triceps. The tendon of this muscle passes across, and is united with, the lower part of the posterior surface of the capsular ligament of the shoulder-joint.

Nerve-supply.—The Teres minor is supplied by the circumflex (axillary) nerve (C. 5).

Action.—The Teres minor rotates the arm laterally.

The **Teres major** (fig. 616) is a thick, somewhat flattened muscle, which arises from the oval area on the dorsal surface of the inferior angle of the scapula, and from the fibrous septa interposed between the muscle and the Teres minor and Infraspinatus; the fibres are directed upwards and laterally and end in a flat tendon, about 5 cm. long, which is inserted into the medial lip of the bicipital groove (intertubercular sulcus) of the humerus. At its insertion the

tendon lies behind that of the Latissimus dorsi, from which it is separated by a bursa, the two tendons being, however, united along their lower borders for a short distance.

Nerve-supply.—The Teres major is supplied by the lower subscapular nerve (C. 5 and 6).

Actions.—The Teres major draws the humerus medially and backwards, and rotates it medially.

IV. The Muscles of the Upper Arm

Coracobrachialis.	Brachialis.
Biceps (brachii).	Triceps.

The **brachial fascia** or deep fascia of the arm is continuous with that covering the Deltoid and the Pectoralis major; it forms a thin, loose sheath for the muscles of the upper arm, and sends septa between them; it is composed of fibres disposed in a circular or spiral direction, and connected together by vertical and oblique fibres. It is thin over the Biceps, but thicker where it covers the Triceps, and over the epicondyles of the humerus: it is strengthened by fibrous aponeuroses, derived from the Pectoralis major and Latissimus dorsi medially, and from the Deltoid laterally. On each side it gives off a strong intermuscular septum, which is attached to the corresponding supracondylar ridge and epicondyle of the humerus.

The *lateral intermuscular septum* extends from the lower part of the lateral lip of the bicipital groove (intertubercular sulcus), along the lateral supracondylar ridge, to the epicondyle; it is blended with the tendon of the Deltoid, gives attachment to the Triceps behind, to the Brachialis, Brachioradialis and Extensor carpi radialis longus in front, and is perforated at the junction of its upper and middle thirds by the radial nerve and the anterior descending branch of the arteria profunda brachii. The *medial intermuscular septum*, thicker than the preceding, extends from the lower part of the medial lip of the bicipital groove (intertubercular sulcus) below the Teres major, along the medial supracondylar ridge to the epicondyle; it is blended with the tendon of the Coracobrachialis, and affords attachment to the Triceps behind and the Brachialis in front. It is perforated by the ulnar nerve, the ulnar collateral artery, and the posterior branch of the supratrochlear (inferior ulnar collateral) artery.

At the elbow, the brachial fascia is attached to the epicondyles of the humerus and the olecranon of the ulna, and is continuous with the antebrachial fascia. Just below the middle of the medial side of the upper arm, an oval opening in the fascia transmits the basilic vein and some lymphatic vessels.

The **Coracobrachialis** (figs. 615, 617) is situated at the upper and medial part of the arm. It arises from the apex of the coracoid process, in common with the tendon of the short head of the Biceps, and by muscular fibres from the upper 10 cm. of this tendon; it is inserted into an impression, from 3 to 5 cm. in length, at the middle part of the medial border of the shaft of the humerus between the origins of the Triceps and Brachialis.

Relations.—*It is perforated by the musculocutaneous nerve*, and is in relation, in *front*, with the Pectoralis major above, and at its insertion with the brachial vessels and median nerve, which cross it; *behind*, with the tendons of the Subscapularis, Latissimus dorsi, and Teres major, the medial head of the Triceps, the humerus and the anterior circumflex humeral vessels; by its *medial border*, with the third part of the axillary artery, the upper part of the brachial artery, the median and musculocutaneous nerves; by its *lateral border*, with the Biceps and Brachialis.

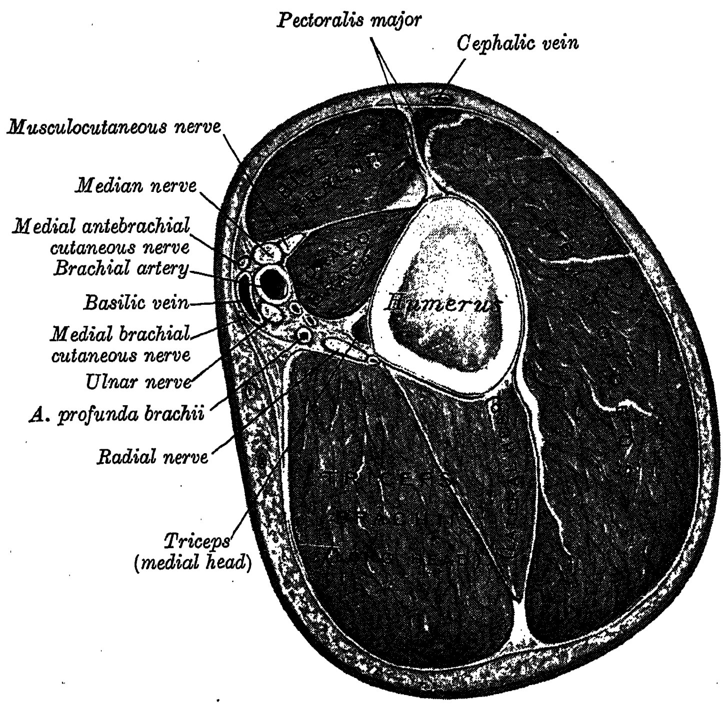
Nerve-supply.—The Coracobrachialis is supplied by the musculocutaneous nerve (C. 7).

Action.—The Coracobrachialis draws the arm forwards and medially.

The **Biceps (brachii)** (figs. 615, 617, 618), a long, fusiform muscle placed on the front of the arm, has received its name from the circumstance that it has two heads of origin. The *short head* arises by a thick flattened tendon from the apex of the coracoid process, in common with the Coracobrachialis. The *long head* takes origin within the capsule of the shoulder-joint. It arises by a long narrow tendon from the supraglenoid tubercle at the apex of the glenoid cavity, and is continuous with the glenoidal labrum (p. 458). The tendon of

the long head, enclosed in a sheath of the synovial membrane of the shoulder-joint, arches over the head of the humerus ; it emerges from the joint through an opening in the capsular ligament close to its humeral attachment and descends in the bicipital groove (intertubercular sulcus) ; it is retained in the groove by the transverse humeral ligament and by a fibrous expansion from the tendon of the Pectoralis major. Each tendon is succeeded by an elongated muscular belly, and the two bellies, although closely applied to each other, can be readily separated until within about 7·5 cm. of the elbow-joint. Here they end in a flattened tendon which is inserted into the rough posterior portion of the tuberosity of the radius, a bursa being interposed between the tendon and the front part of the tuberosity. As the tendon of the muscle approaches the radius

FIG. 617.—A transverse section through the upper arm at the junction of the proximal with the middle one-third of the humerus.



it is twisted upon itself, so that its anterior surface becomes lateral and is applied to the tuberosity of the radius at its insertion. Opposite the bend of the elbow the tendon gives off, from its medial side, a broad aponeurosis, named the *bicipital aponeurosis* (*lacertus fibrosus*), which passes obliquely downwards and medially across the brachial artery and is continuous with the deep fascia covering the origins of the flexor muscles of the forearm (fig. 614). With very little force the tendon of insertion can be split down to the radial tuberosity, when it can be seen that the anterior portion of the tendon receives the fibres of the short head, and the posterior portion those of the long head.

A third head to the Biceps is occasionally found, arising at the upper and medial part of the Brachialis, with which it is blended, and inserted into the bicipital aponeurosis and medial side of the tendon of the muscle ; in most cases this additional slip lies behind the brachial artery. In some instances the third head consists of two slips, which pass down, one in front of, the other behind the artery.

Relations.—The Biceps is overlapped above by the Pectoralis major and Deltoid ; in the rest of its extent it is covered by the fasciæ and skin. Its long head passes through the shoulder-joint, and its short head rests on the joint and on the upper part of the humerus ; below, it lies on the Brachialis, the musculocutaneous nerve, and the Supinator. Its *medial border* is in relation with the Coracobrachialis, and overlaps the brachial vessels and median nerve ; its *lateral border* is in relation with the Deltoid and Brachioradialis.

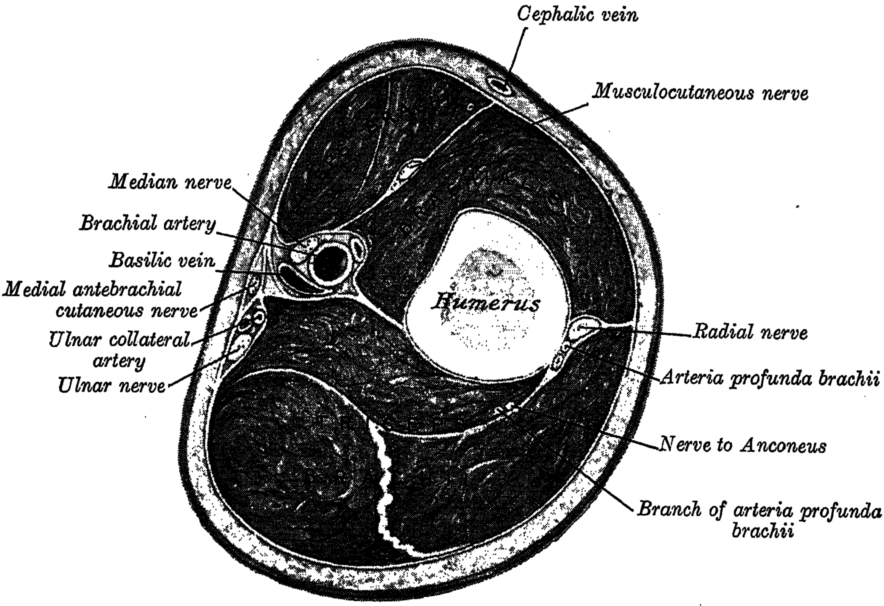
Nerve-supply.—The Biceps is supplied by the musculocutaneous nerve (C. 5 and *6*).

Actions.—The Biceps is a powerful supinator of the forearm ; it also flexes the elbow-joint, and to a slight extent the shoulder-joint. Through the bicipital aponeurosis it is a tensor of the antebrachial fascia.

Applied Anatomy.—The long tendon of the Biceps is sometimes dislocated from its groove on the humerus. When this occurs, the arm is fixed in a position of abduction, but the head of the humerus can be felt in its proper position. The tendon can generally be replaced by flexing the forearm on the arm and rotating the limb. Rupture of the long tendon of the Biceps may also take place.

The **Brachialis** (figs. 615, 618, 619) covers the front of the elbow-joint and the lower one-half of the humerus. It arises from the lower one-half of the front of the humerus, commencing above at the insertion of the Deltoid, which

Fig. 618.—A transverse section through the upper arm, a little below the middle of the shaft of the humerus.



it embraces by two pointed processes, and extending below to within 2·5 cm. of the margin of the articular surface. It also arises from the intermuscular septa, but more extensively from the medial than from the lateral ; it is separated from the lower part of the lateral intermuscular septum by the Brachioradialis and Extensor carpi radialis longus. Its fibres converge to a thick tendon which is inserted into the tuberosity of the ulna and the rough depression on the anterior surface of the coronoid process.

Relations.—It is in relation, in *front*, with the Biceps, the brachial vessels, musculocutaneous and median nerves ; *behind*, with the humerus and articular capsule of the elbow-joint ; by its *medial border*, with the Pronator teres, and with the medial intermuscular septum, which separates it from the Triceps and the ulnar nerve ; by its *lateral border*, with the radial nerve, radial recurrent and the anterior descending branch of the profunda brachii arteries, the Brachioradialis and Extensor carpi radialis longus.

Nerve-supply.—The Brachialis is chiefly supplied by the musculocutaneous nerve (C. 6 and 7), but receives an additional filament from the radial nerve (C. 7).

Action.—The Brachialis flexes the elbow-joint.

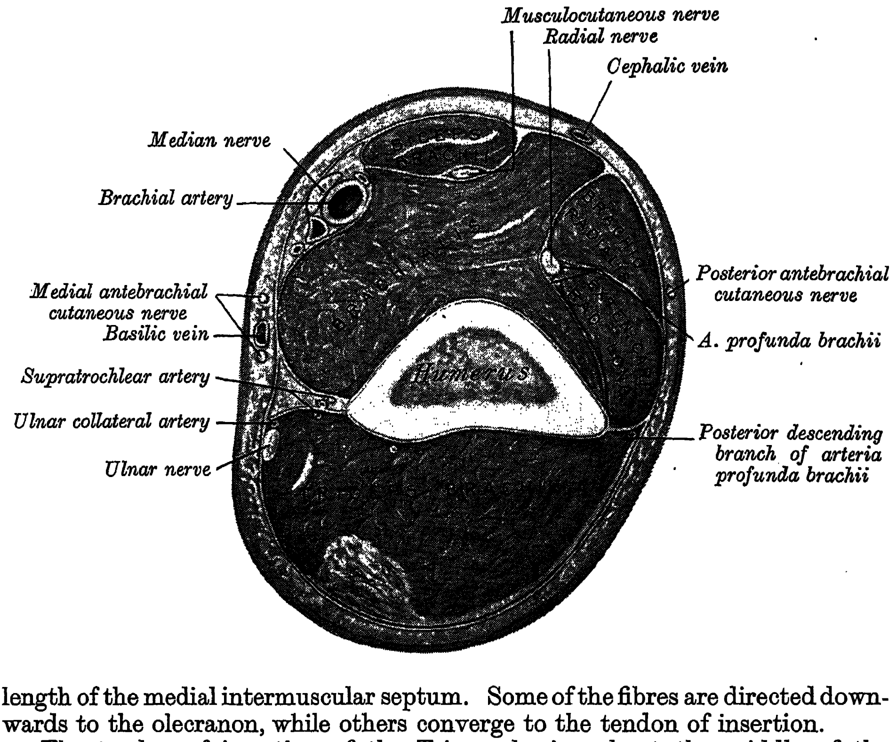
The **Triceps** (figs. 616 to 619), situated on the back of the upper arm, is of large size, and arises by three heads (long, lateral and medial), hence its name.

The *long head* arises by a flattened tendon from the infraglenoid tubercle of the scapula, being blended at its upper part with the capsular ligament of the shoulder-joint ; the muscular fibres pass downwards along the medial side of the lateral head and superficial to the medial head, and join with them in the tendon of insertion.

The *lateral head* arises from a narrow ridge on the posterior surface of the shaft of the humerus, extending from near the insertion of the Teres minor to the upper part of the spiral groove (sulcus for the radial nerve), and from the lateral border of the humerus and the lateral intermuscular septum ; the fibres from this origin converge towards the tendon of insertion.

The *medial head*, which is covered posteriorly by the lateral and the long heads, arises from the posterior surface of the shaft of the humerus, below the spiral groove ; it is narrow and pointed above, and extends from the insertion of the Teres major to within 2·5 cm. of the trochlea of the humerus ; it also arises from the medial border of the bone and from the back of the whole

Fig. 619.—A transverse section through the upper arm, 2 cm. proximal to the medial epicondyle of the humerus.



length of the medial intermuscular septum. Some of the fibres are directed downwards to the olecranon, while others converge to the tendon of insertion.

The tendon of insertion of the Triceps begins about the middle of the muscle. It consists of two aponeurotic laminæ, one of which covers the back of the lower one-half of the muscle ; the other is more deeply seated in the substance of the muscle. After receiving the attachment of the muscular fibres, the two lamellæ unite above the elbow, and are inserted, for the most part, into the posterior portion of the upper surface of the olecranon ; on the lateral side a band of fibres is continued downwards, over the Anconeus, to blend with the antebrachial fascia.

The long head of the Triceps descends between the Teres minor and Teres major, dividing the triangular space between these two muscles and the humerus into two smaller spaces, one triangular, the other quadrangular (fig. 616). The triangular space contains the circumflex scapular vessels ; it is bounded by the Teres minor above, the Teres major below, and the long head of the Triceps laterally. The quadrangular space transmits the posterior circumflex humeral vessels and the circumflex (axillary) nerve ; it is bounded by the Subscapularis, the Teres minor and the *capsular ligament of the shoulder-joint* above, the Teres major below, the long head of the Triceps medially, and the humerus laterally.

The **Subanconeus** is the name given to a few fibres which spring from the deep surface of the lower part of the Triceps, and are inserted into the posterior part of the articular capsule of the elbow-joint.

Nerves.—The Triceps is supplied by the radial nerve (C. *6*, 7, and *8*).*

Actions.—The Triceps is the great extensor muscle of the forearm. When the arm is extended, the long head of the muscle may assist in drawing the humerus backwards and in adducting it to the thorax. The long head supports the under part of the capsule of the shoulder-joint, when the arm is raised from the side. The Subanconeus draws up the posterior part of the articular capsule of the elbow-joint during extension of the forearm.

Applied Anatomy.—The insertion of the Triceps into the deep fascia of the forearm is of importance in the operation of excision of the elbow, and should always be carefully preserved. By means of it the patient is enabled to extend the forearm, a movement which would otherwise be accomplished mainly by gravity—that is to say, by allowing the forearm to drop by its own weight.

V. The Muscles of the Forearm

The **antebrachial fascia** (deep fascia of the forearm), continuous above with the brachial fascia, is a dense investment which forms a general sheath for the muscles in this region; it is attached, behind, to the olecranon and posterior border of the ulna, and sends off from its deep surface numerous intermuscular septa. It gives origin to muscular fibres, especially at the upper part of the medial and lateral sides of the forearm, and also ensheathes the different muscles; transverse septa are given off both on the anterior and posterior surfaces of the forearm, separating the deep from the superficial layer of muscles. It is much thicker on the posterior than on the anterior surface, and at the lower than at the upper part of the forearm, and is strengthened above by tendinous fibres derived from the Biceps in front, and from the Triceps behind. In the region of the carpus there are two localised thickenings in the fascia, termed the *flexor* (p. 609) and *extensor retinacula* (p. 612) (transverse and dorsal carpal ligaments). These two bands retain the digital tendons in position and so increase the efficiency of their actions on the fingers. Apertures exist in the fascia for the passage of vessels and nerves; one of these apertures, of large size and situated at the front of the elbow, transmits a communicating branch between the superficial and deep veins.

The antebrachial or forearm muscles consist of an anterior and a posterior group.

1. The Anterior Antebrachial Muscles

These muscles are divided for convenience of description into two groups, superficial and deep.

(*a*) *Superficial Group* (fig. 620)

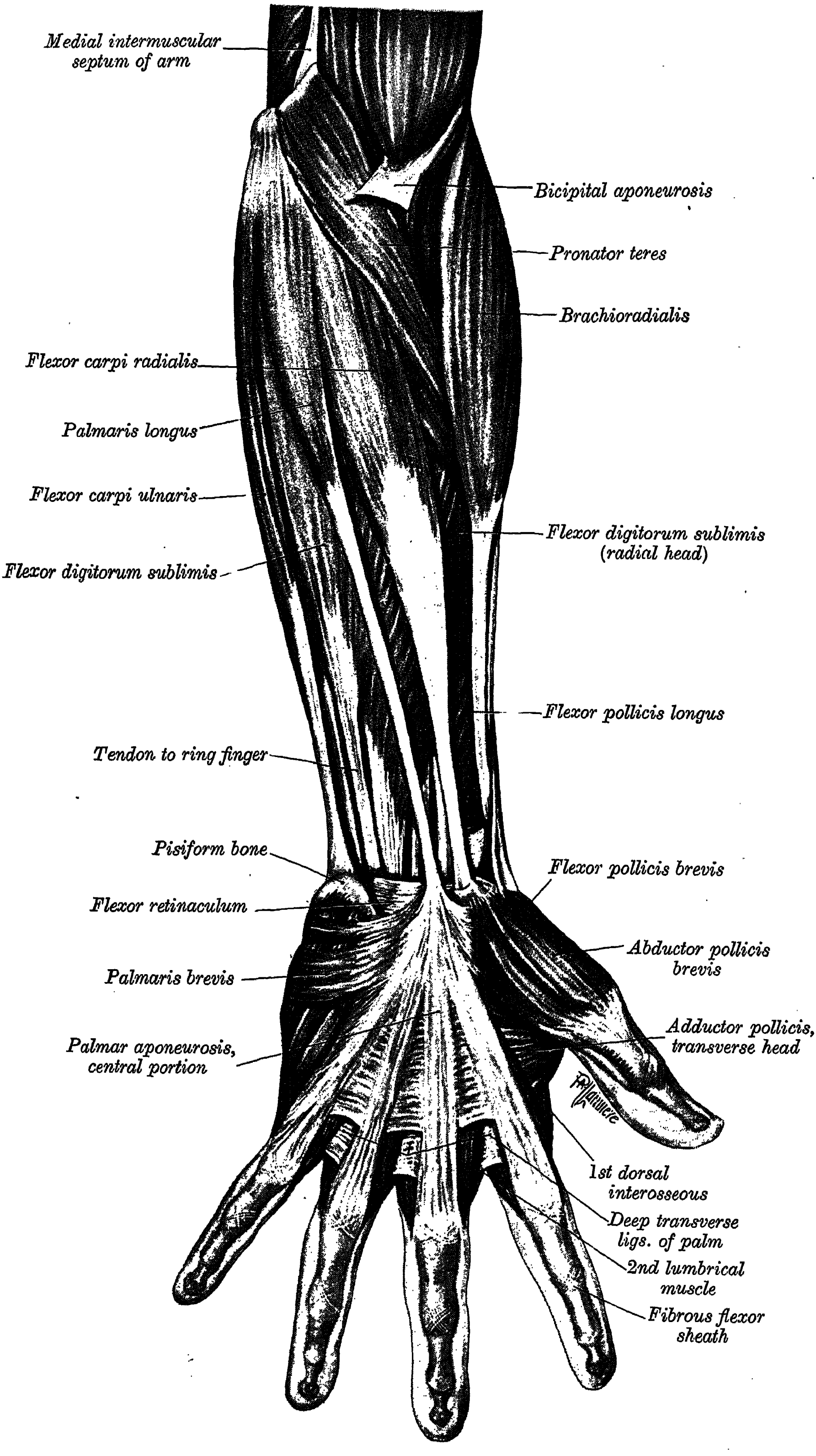
Pronator teres.	Palmaris longus.
Flexor carpi radialis.	Flexor carpi ulnaris.
Flexor digitorum sublimis.	

The muscles of this group take origin from the medial epicondyle of the humerus by a common tendon; they receive additional fibres from the antebrachial fascia near the elbow, and from the septa which pass from this fascia between the individual muscles.

The **Pronator teres** (figs. 620, 621) has a humeral and an ulnar head of origin. The *humeral head*, the larger and more superficial, arises immediately above the medial epicondyle, and from the tendon common to the origin of the other muscles; also from the intermuscular septum between it and the Flexor carpi radialis and from the antebrachial fascia. The much smaller *ulnar head* arises from the medial side of the coronoid process of the ulna below the origin of the flexor digitorum sublimis, and joins the humeral head at an acute angle. The median nerve enters the forearm between the heads of the muscle, and is separated from the ulnar artery by the ulnar head. The muscle passes obliquely across the forearm and ends in a flat tendon, which is inserted into a rough

* Wilfred Harris (*Journal of Anatomy*, vol. xxxviii.) is of opinion that the Triceps is mainly supplied by the sixth and seventh cervical nerves.

Fig. 620.—The superficial flexor muscles of the right forearm, the palmar aponeurosis and the digital fibrous flexor sheaths.



impression on the middle of the lateral surface of the shaft of the radius. The lateral border of the muscle forms the medial boundary of the triangular hollow which is situated in front of the elbow-joint, and contains the median nerve, brachial artery, and tendon of the Biceps.

Nerve-supply.—The Pronator teres is supplied by the median nerve (C. 6).

Actions.—The Pronator teres rotates the radius upon the ulna, turning the palm of the hand backwards, i.e. it pronates the forearm and hand; it also helps to flex the elbow-joint, when great force is required.

The **Flexor carpi radialis** (figs. 620, 621, 624) lies on the medial side of the Pronator teres. It arises from the medial epicondyle by the common tendon, from the antebrachial fascia, and from the intermuscular septa between it and the adjacent muscles. Its fleshy belly is fusiform in shape and, rather more than halfway down the forearm, ends in a long tendon, which passes through a canal in the lateral part of the flexor retinaculum (transverse carpal ligament) and occupies a groove on the trapezium (greater multangular bone); this groove is lined by a synovial sheath. The tendon is inserted into the palmar surface of the base of the second metacarpal bone, and sends a slip to the base of the third metacarpal bone. These bony attachments are hidden by the origin of the oblique head of the adductor pollicis (fig. 633). In the lower part of the forearm the radial artery lies between the tendon of this muscle and that of the Brachioradialis.

Nerve-supply.—The Flexor carpi radialis is supplied by the median nerve (C. 6).

Actions.—Acting with the Flexor carpi ulnaris, the Flexor carpi radialis flexes the wrist; acting with the radial extensors of the wrist, it helps to abduct the hand. It participates, as a synergic muscle, in flexion of the fingers.

The **Palmaris longus** (figs. 620, 621, 632) is a slender, fusiform muscle, lying on the medial side of the Flexor carpi radialis. It arises from the medial epicondyle of the humerus by the common tendon, from the intermuscular septa between it and the adjacent muscles, and from the antebrachial fascia. It ends in a long slender tendon, which passes in front of the flexor retinaculum (transverse carpal ligament), and is inserted into the anterior surface of the distal one-half of this structure and into the central part of the palmar aponeurosis, frequently sending a tendinous slip to the short muscles of the thumb. Just above the wrist the median nerve lies deep to the tendon, and projects a little beyond its lateral edge.

This muscle is often absent, and is subject to very considerable variations: it may be tendinous above and muscular below, or muscular in the middle with a tendon above and below; it may consist of two muscular bundles with a central tendon; or it may be represented solely by a tendinous band.

Nerve-supply.—The Palmaris longus is supplied by the median nerve (C. 8).

Actions.—The Palmaris longus tightens the palmar aponeurosis and flexes the wrist.

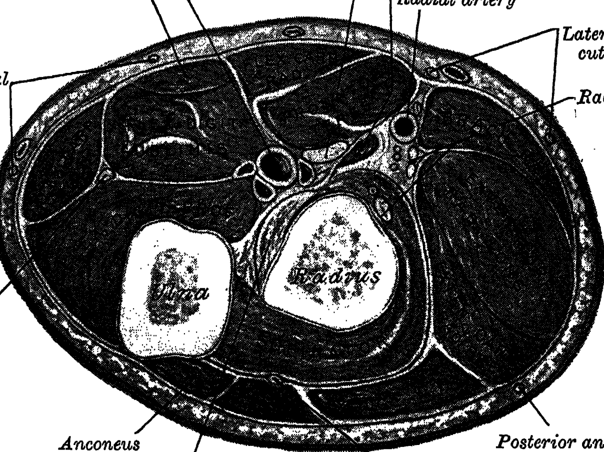
The **Flexor carpi ulnaris** (figs. 620, 621, 624) lies along the ulnar side of the forearm. It arises by two heads, humeral and ulnar, connected by a tendinous arch, beneath which the ulnar nerve passes downwards and the posterior ulnar recurrent artery upwards. The *humeral head* is very small and arises from the medial epicondyle of the humerus by the common tendon; the *ulnar head* arises from the medial margin of the olecranon, and from the upper two-thirds of the posterior border of the ulna by an aponeurosis common to it and the Extensor carpi ulnaris and Flexor digitorum profundus, and from the intermuscular septum between it and the Flexor digitorum sublimis. The fibres end in a tendon which is formed along the anterolateral border of the muscle in its distal one-half and is inserted into the pisiform bone, whence it is prolonged to the hamate and fifth metacarpal bones by the pisohamate and pisometacarpal ligaments (p. 474); it is also attached by a few fibres to the flexor retinaculum. The ulnar vessels and nerve lie on the lateral side of its tendon of insertion.

Nerve-supply.—The Flexor carpi ulnaris is supplied by the ulnar nerve (C. 8 and T. *1*).

Actions.—Acting with the Flexor carpi radialis, the Flexor carpi ulnaris flexes the wrist; acting with the Extensor carpi ulnaris, it is a powerful adductor of the hand. It participates, as a synergic muscle, in flexion of the fingers.

The **Flexor digitorum sublimis** (figs. 620, 621, 624) is deep to the preceding muscles; it is the largest of the muscles of the superficial group, and arises by two heads, humero-ulnar and radial. The *humero-ulnar head* arises from the medial epicondyle of the humerus by the common tendon, from the anterior portion of the medial (ulnar collateral) ligament of the elbow, from the intermuscular septa between it and the preceding muscles, and from the medial side of the coronoid process, above the ulnar origin of the Pronator teres. The *radial head,* which is a thin sheet of muscle, arises from the anterior border of the radius, extending from the radial tuberosity to the insertion of the Pronator teres. The median nerve and the ulnar artery pass downwards through the gap which intervenes between these two heads. The muscle speedily separates into two strata of muscular fibres, superficial and deep; the superficial stratum, which is joined on its lateral side by the radial head, divides into two parts, which end in tendons for the middle and ring fingers; the deep stratum gives

FIG. 621.—A transverse section through the forearm at the level of the radial tuberosity.



off a muscular slip to join that part of the superficial plane which is associated with the tendon of the ring finger, and then divides into two parts, which end in tendons for the index and little fingers. As the four tendons pass behind the flexor retinaculum (transverse carpal ligament), they are arranged in pairs, the superficial pair going to the middle and ring, the deep pair to the index and little fingers. The tendons diverge from one another in the palm and opposite the bases of the proximal phalanges each divides into two slips, to allow of the passage of the corresponding tendon of the Flexor digitorum profundus; the surfaces of the two slips become reversed and they then reunite, partially decussate, and so form a grooved channel for the reception of the tendon of the Flexor digitorum profundus. Finally the tendon divides and is inserted into the sides of the shaft of the middle phalanx.

Nerve-supply.—The Flexor digitorum sublimis is supplied by the median nerve (C. 7 and 8 and T. *1*).

Actions.—The Flexor digitorum sublimis flexes first the middle and then the proximal phalanges. It can also act as a flexor of the wrist.

Relations.—*In the forearm.* The Flexor digitorum sublimis is covered by the Palmaris longus, Flexor carpi radialis, Pronator teres, Brachioradialis, the radial artery and the radial nerve. It is placed in front of the Flexor digitorum profundus, the upper part of the ulnar artery, the median nerve (which is closely bound to it by fibro-areolar tissue) and the Flexor pollicis longus. *At the wrist,* the tendons of the Flexor digitorum sublimis pass

behind the flexor retinaculum, lying in front of the tendons of the Flexor digitorum profundus and sharing a common synovial sheath with them (fig. 629). The Flexor pollicis longus tendon and the median nerve lie to their lateral side. *In the hand,* the tendons lie behind the palmar aponeurosis, the superficial palmar (volar) arch and the digital branches of the median and ulnar nerves, but in front of the tendons of the Flexor digitorum profundus and the lumbrical muscles.

(*b*) *Deep Group* (fig. 622)

Flexor digitorum profundus. Flexor pollicis longus.
Pronator quadratus.

The **Flexor digitorum profundus** (figs. 621, 622, 624) is situated on the ulnar side of the forearm, deep to the superficial flexors. It arises from the upper three-fourths of the anterior and medial surfaces of the shaft of the ulna, embracing the insertion of the Brachialis above, and extending to within a short distance of the Pronator quadratus below. It also arises from a depression on the medial side of the coronoid process of the ulna, and from the upper three-fourths of the posterior border of the bone by an aponeurosis, in common with the Flexor and Extensor carpi ulnaris ; it also springs from the anterior surface of the ulnar half of the interosseous membrane. The muscle ends in four tendons, which run behind the flexor retinaculum deep to the tendons of the Flexor digitorum sublimis. The portion of the muscle for the index finger is usually distinct throughout, but the tendons for the middle, ring and little fingers are connected together by areolar tissue and tendinous slips, as far as the palm of the hand. Opposite the proximal phalanges the tendons pass through the openings in the tendons of the Flexor digitorum sublimis, and they are inserted into the palmar surfaces of the bases of the distal phalanges.

Nerve-supply.—The medial part of the Flexor digitorum profundus is supplied by the ulnar nerve and its lateral part by the anterior interosseous branch of the median nerve (C. *7* and 8 and T. *1*).

Actions.—The Flexor digitorum profundus flexes the distal phalanges, after the Flexor digitorum sublimis has bent the middle phalanges ; it can also assist in flexing the wrist.

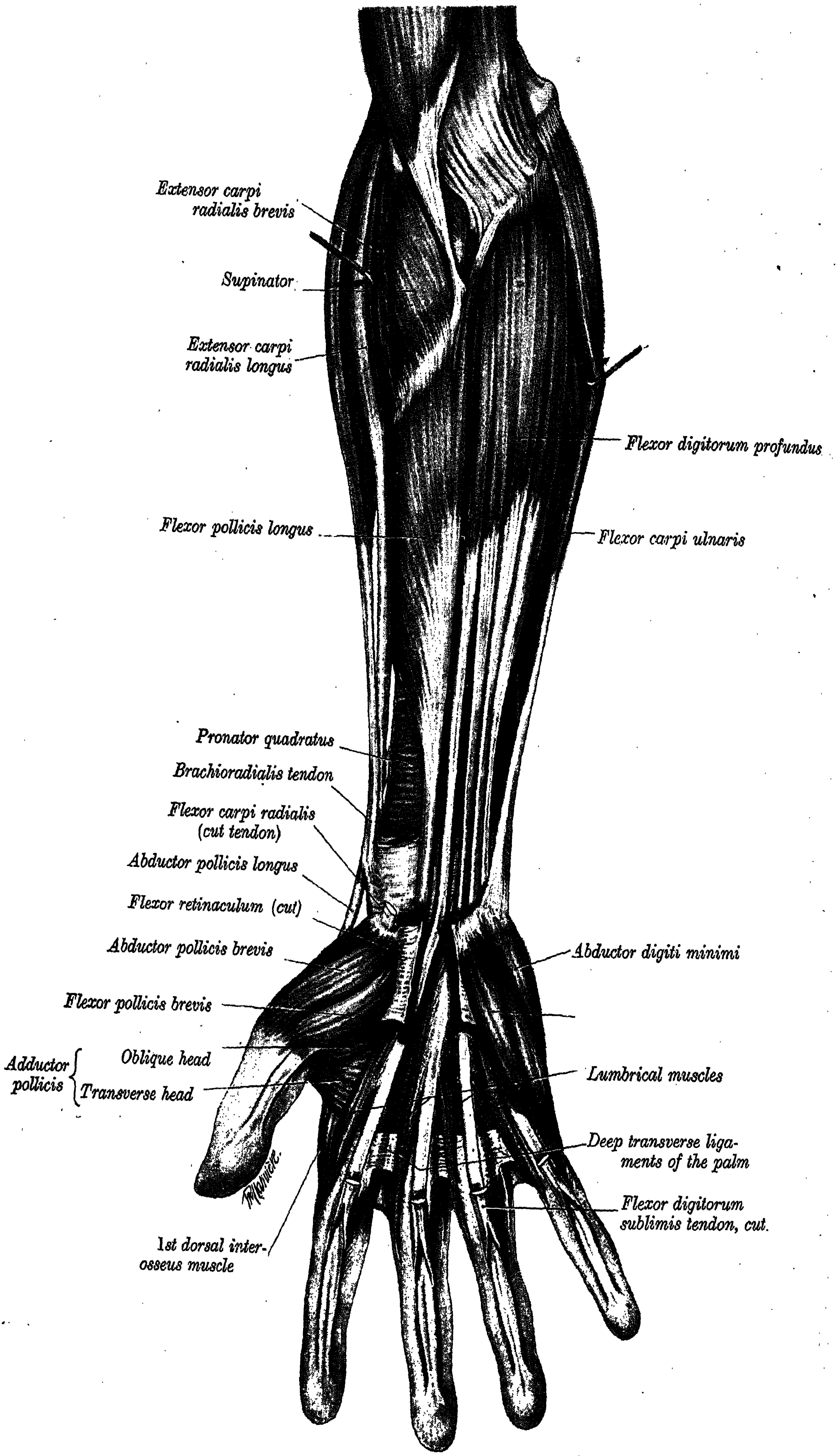
Four small muscles, named the Lumbricales, are connected with the tendons of the Flexor digitorum profundus in the palm, and are described with the muscles of the hand (p. 619).

Fibrous sheaths of the flexor tendons.—After leaving the palm, the tendons of the Flexores digitorum sublimis et profundus lie in osseo-aponeurotic canals (figs. 630, 635), formed behind by the phalanges, and in front by fibrous bands which arch across the tendons, and are attached on each side to the margins of the phalanges and to the palmar ligaments of the interphalangeal joints. Opposite the middle of the proximal and middle phalanges the bands (*digital vaginal ligaments*) are very strong, and the fibres are transverse ; but opposite the joints they are much thinner, and consist of *annular* and *cruciate* fibres. Each canal is lined by a synovial sheath, which is reflected on to the contained tendons.

As the flexor tendons approach their insertions they are connected to the dorsal parts of the enclosing synovial sheaths by triangular and thread-like bands of synovial membrane. These bands, termed *vincula tendinum* (fig. 623), convey minute vessels to the tendons, and are of two kinds, (*a*) vincula brevia and (*b*) vincula longa.

The *vincula brevia,* two in number in each finger, are triangular bands attached to the deep surfaces of the tendons close to their insertions ; one connects the tendon of the Flexor digitorum sublimis to the front of the proximal interphalangeal joint and adjacent part of the proximal phalanx, and the other the tendon of the Flexor digitorum profundus to the front of the distal interphalangeal joint and adjacent part of the middle phalanx. The *vincula longa* are thread-like slips, of which two are usually attached to each tendon of the Flexor digitorum sublimis, and one to each tendon of the Flexor digitorum profundus. Those of the Flexor digitorum sublimis are connected to the slips of that tendon where these fold over the tendon of the Flexor digitorum pro-

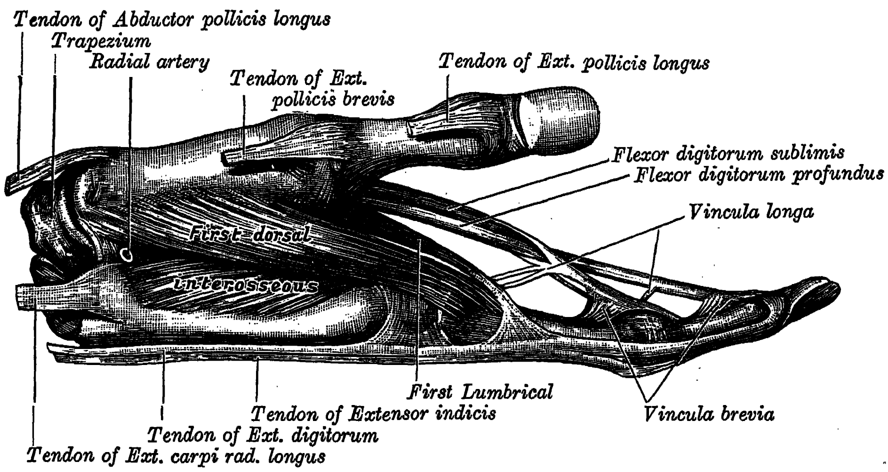
FIG. 622.—The deep muscles of the front of the right fore-arm.



fundus, and, passing one on each side of the latter tendon, are attached to the sheath at the lateral margins of the proximal end of the proximal phalanx. That of the tendon of the Flexor digitorum profundus is fixed to its tendon shortly after the latter has pierced the tendon of the Flexor digitorum sublimis. It runs upwards and backwards, perforates one of the two slips of the latter tendon, or passes between the two slips ; thereafter it blends with the vinculum breve of the Flexor digitorum sublimis, and is attached to the dorsal wall of the synovial sheath at the distal end of the proximal phalanx.

The **Flexor pollicis longus** (figs. 622, 624) is situated on the radial side of the forearm in the same plane as the Flexor digitorum profundus. It arises from the grooved, anterior surface of the shaft of the radius, extending from immediately below the tuberosity to within a short distance of the Pronator quadratus. It arises also from the adjacent part of the interosseous membrane, and generally by a fusiform, fleshy slip from the medial border of the coronoid process, distal to the Flexor digitorum sublimis and Pronator teres, or from the

FIG. 623.—The tendons and the vincula tendinum of the right index finger. Lateral aspect.



medial epicondyle of the humerus. The fibres end in a flattened tendon, which passes behind the flexor retinaculum, is then lodged between the opponens pollicis and the oblique head of the Adductor pollicis, and, entering an osseo-aponeurotic canal similar to those for the flexor tendons of the fingers, is inserted into the palmar surface of the base of the distal phalanx of the thumb. The anterior interosseous nerve and vessels descend on the front of the interosseous membrane between the Flexor pollicis longus and Flexor digitorum profundus.

Nerve-supply.—The Flexor pollicis longus is supplied by the anterior interosseous branch of the median nerve (C. 8 and T. *1*).

Actions.—The Flexor pollicis longus is a flexor of the phalanges of the thumb ; it can also act as a flexor of the wrist.

The **Pronator quadratus** (figs. 622, 628) is a flat, quadrilateral muscle, extending across the front of the lower parts of the radius and ulna. It arises from the oblique ridge on the lower part of the anterior surface of the shaft of the ulna (fig. 411) ; from the medial part of the anterior surface of the lower one-fourth of the ulna ; and from a strong aponeurosis which covers the medial one-third of the muscle. The fibres pass laterally and slightly downwards, to be inserted into the lower one-fourth of the anterior border and surface of the shaft of the radius ; the deeper fibres are inserted into the triangular area above the ulnar notch of the radius.

Nerve-supply.—The Pronator quadratus is supplied by the anterior interosseous branch of the median nerve (C. 6 and 7).

Action.—The Pronator quadratus pronates the forearm, i.e. turns it so that the palm of the hand is directed backwards.

2. The Posterior Antebrachial Muscles

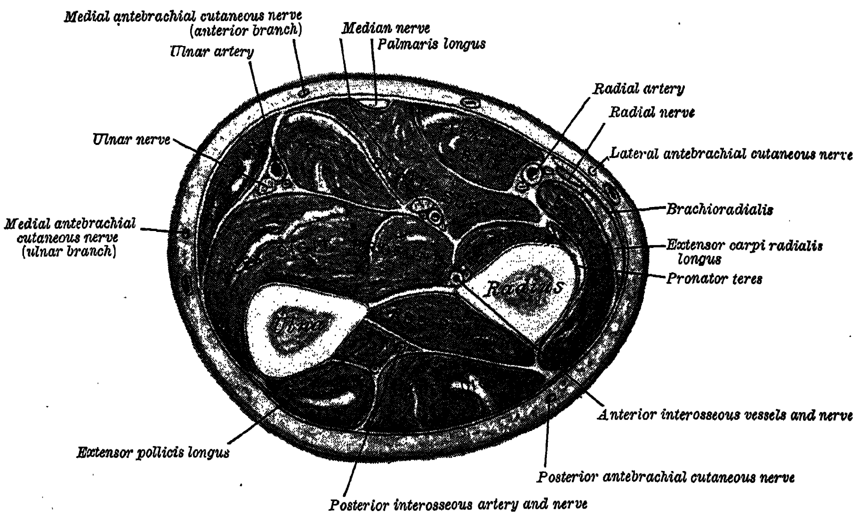
These muscles are divided for convenience of description into two groups, superficial and deep.

(a) *Superficial Group* (fig. 625)

Brachioradialis.	Extensor digitorum.
Extensor carpi radialis longus.	Extensor digiti minimi.
Extensor carpi radialis brevis.	Extensor carpi ulnaris.
Anconeus.	

The **Brachioradialis** (figs. 620, 621, 625) is the most superficial muscle on the radial side of the forearm. It arises from the upper two-thirds of the lateral

Fig. 624.—A transverse section through the middle of the forearm.



supracondylar ridge of the humerus, and from the front of the lateral intermuscular septum. The radial nerve and the anastomosis between the arteria profunda brachii and the radial recurrent artery are interposed between it and the Brachialis. The fibres end above the middle of the forearm in a flat tendon which is inserted into the lateral side of the lower end of the radius, immediately above the styloid process. The tendon is crossed at its insertion by the tendons of the Abductor pollicis longus and Extensor pollicis brevis ; the radial artery is on its ulnar side.

Nerve-supply.—The Brachioradialis is supplied by the radial nerve (C. 5 and 6).

Action.—The Brachioradialis is a flexor of the elbow-joint, but is supplied by the nerve of the extensor muscles, i.e. the radial nerve. It acts to best advantage when the forearm is in the midprone position.

The **Extensor carpi radialis longus** (figs. 621, 625) is partly covered by the Brachioradialis. It arises mainly from the lower one-third of the lateral supracondylar ridge of the humerus and from the front of the lateral intermuscular septum, but it receives a few fibres from the common tendon of origin of the extensor muscles of the forearm. The muscle ends at the junction of the upper and middle thirds of the forearm in a flat tendon, which runs along the lateral border of the radius, deep to the Abductor pollicis longus and Extensor pollicis brevis ; it then passes under cover of the extensor retinaculum (dorsal carpal ligament), where it lies on the back of the radius in a groove immediately behind the styloid process. It is inserted into the radial side of the dorsal surface of the base of the second metacarpal bone.

Nerve-supply.—The Extensor carpi radialis longus is supplied by the radial nerve (C. 6 and 7).

The **Extensor carpi radialis brevis** (figs. 621, 624, 625) is shorter than the preceding muscle and is covered by it. It arises from the lateral epicondyle of the humerus, by a tendon common to it and the next three muscles ; from the lateral ligament of the elbow-joint ; from a strong aponeurosis which covers its surface ; and from the intermuscular septa between it and the adjacent muscles. The fibres end about the middle of the forearm in a flat tendon which closely accompanies that of the preceding muscle to the wrist ; it passes deep to the Abductor pollicis longus and Extensor pollicis brevis, then under cover of the extensor retinaculum (dorsal carpal ligament), and is inserted into the dorsal surface of the base of the third metacarpal bone, on its radial side and distal to its styloid process, and into the adjoining part of the base of the second metacarpal bone. Under the extensor retinaculum the tendon lies on the back of the radius in a shallow groove, on the ulnar side of the groove which lodges the tendon of the Extensor carpi radialis longus, and separated from it by a faint ridge.

The tendons of the two preceding muscles pass through the same compartment of the extensor retinaculum in a single synovial sheath.

Nerve-supply.—The Extensor carpi radialis brevis is supplied by the posterior interosseous nerve (deep branch of the radial nerve) (C. 6 and 7).

Actions.—Both the preceding muscles, working with the Extensor carpi ulnaris, extend the wrist ; working with the Flexor carpi radialis, they abduct the hand. Both participate as synergic muscles in flexion of the fingers.

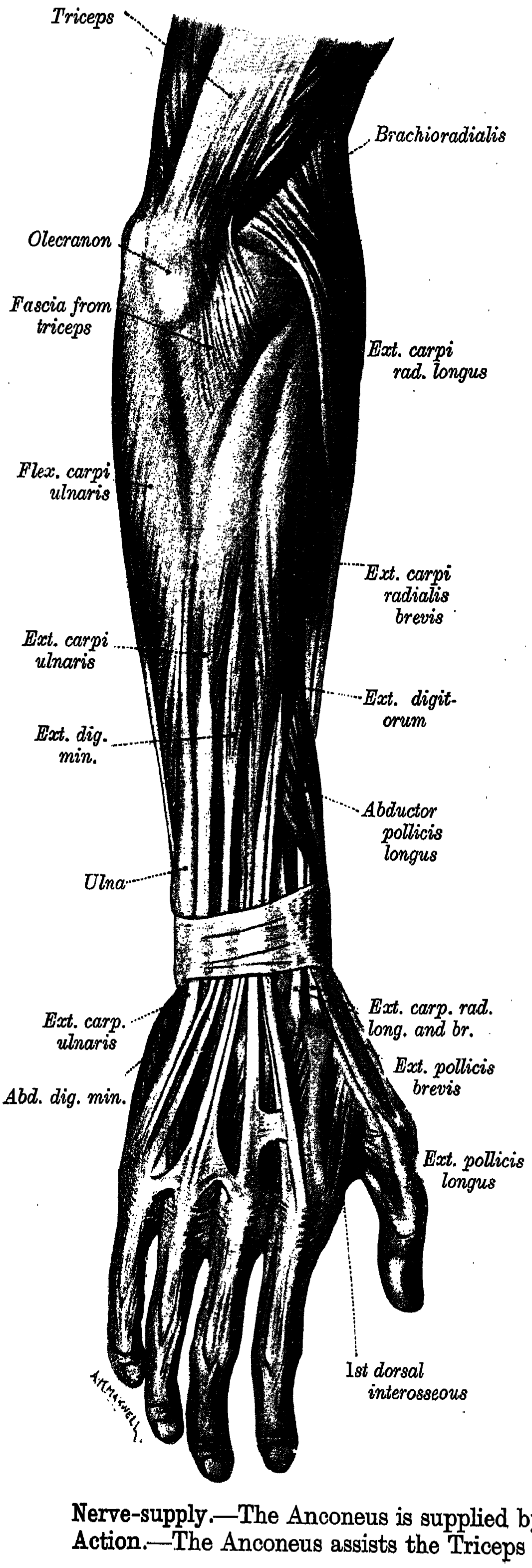
The **Extensor digitorum** (Extensor digitorum communis) (figs. 621, 624, 625) arises from the lateral epicondyle of the humerus by the common tendon ; from the intermuscular septa between it and the adjacent muscles, and from the antebrachial fascia. It divides below into four tendons, which pass, together with that of the Extensor indicis, through a compartment of the extensor retinaculum (dorsal carpal ligament), within a synovial sheath. The tendons then diverge on the back of the hand, and are inserted in the following manner. Opposite the metacarpophalangeal joint each tendon is bound by fasciculi to the collateral ligaments, and serves as the dorsal ligament of this joint ; after crossing the joint, it spreads into an aponeurosis which covers the dorsal surface of the proximal phalanx and is there reinforced by the corresponding tendons of the Interosseous and Lumbrical muscles. Opposite the proximal interphalangeal joint this aponeurosis divides into three slips, an intermediate and two collateral : the intermediate is inserted into the base of the middle phalanx ; the two collateral are continued onwards along the sides of the middle phalanx, and uniting by their contiguous margins, are inserted into the dorsal surface of the base of the distal phalanx. As the tendons cross the interphalangeal joints, they serve as their dorsal ligaments. The tendon to the index finger is accompanied by the Extensor indicis, which lies on its ulnar side. On the back of the hand, the tendons to the middle, ring and little fingers are connected by two obliquely placed bands, one from the third tendon passing downwards and laterally to the second tendon, and the other passing from the fourth to the third. Occasionally the second tendon is connected to the first by a thin, oblique band.

Nerve-supply.—The Extensor digitorum is supplied by the posterior interosseous nerve (deep branch of radial nerve) (C. 7).

Actions.—Owing to its attachments to the collateral ligaments of the metacarpophalangeal joints the Extensor digitorum acts only on the proximal phalanges, the middle and distal phalanges being extended by the Interosseous and Lumbrical muscles ; it tends to separate the fingers as it extends them. When required, it can assist in extending the wrist.

The **Extensor digiti minimi** (Extensor digiti quinti proprius) (fig. 625) is a slender muscle, medial to, and usually connected with, the Extensor digitorum. It arises from the common extensor tendon by a thin tendinous slip, and from the intermuscular septa between it and the adjacent muscles. Its tendon runs through a compartment of the extensor retinaculum behind the inferior radio-ulnar joint, then divides into two as it crosses the hand, and finally joins the expansion of the Extensor digitorum tendon on the dorsum of the proximal phalanx of the fifth digit.

FIG. 625.—Muscles of extensor aspect of forearm, superficial layer. (From Quain's *Anatomy*, XI. Edition.)



Nerve-supply.—The Extensor digiti minimi is supplied by the posterior interosseous nerve (C. 7).

Actions.—The Extensor digiti minimi extends the little finger at the metacarpophalangeal joint and can assist in extending the wrist.

The **Extensor carpi ulnaris** (figs. 624, 625) arises from the lateral epicondyle of the humerus, by the common extensor tendon; from the posterior border of the ulna by an aponeurosis in common with the Flexor carpi ulnaris and the Flexor digitorum profundus; and from the antebrachial fascia. It ends in a tendon which runs in the groove between the head and the styloid process of the ulna, passing through a separate compartment of the extensor retinaculum (dorsal carpal ligament), and is inserted into the tubercle on the ulnar side of the base of the fifth metacarpal bone.

Nerve-supply.—The Extensor carpi ulnaris is supplied by the posterior interosseous nerve (C. 7).

Actions.—The Extensor carpi ulnaris, acting with the Extensores carpi radiales, extends the wrist; acting with the Flexor carpi ulnaris it adducts the hand. In addition it functions as a synergic muscle in flexion of the fingers.

The **Anconeus** (figs. 625, 626) is a small, triangular muscle on the back of the elbow-joint, and appears to be a continuation of the Triceps. It arises by a separate tendon from the posterior surface of the lateral epicondyle of the humerus; its fibres diverge as they pass medially to reach the ulna, covering the posterior aspect of the annular ligament. They are inserted into the lateral side of the olecranon, and upper one-fourth of the posterior surface of the shaft of the ulna.

Nerve-supply.—The Anconeus is supplied by the radial nerve (C. 7 and 8).

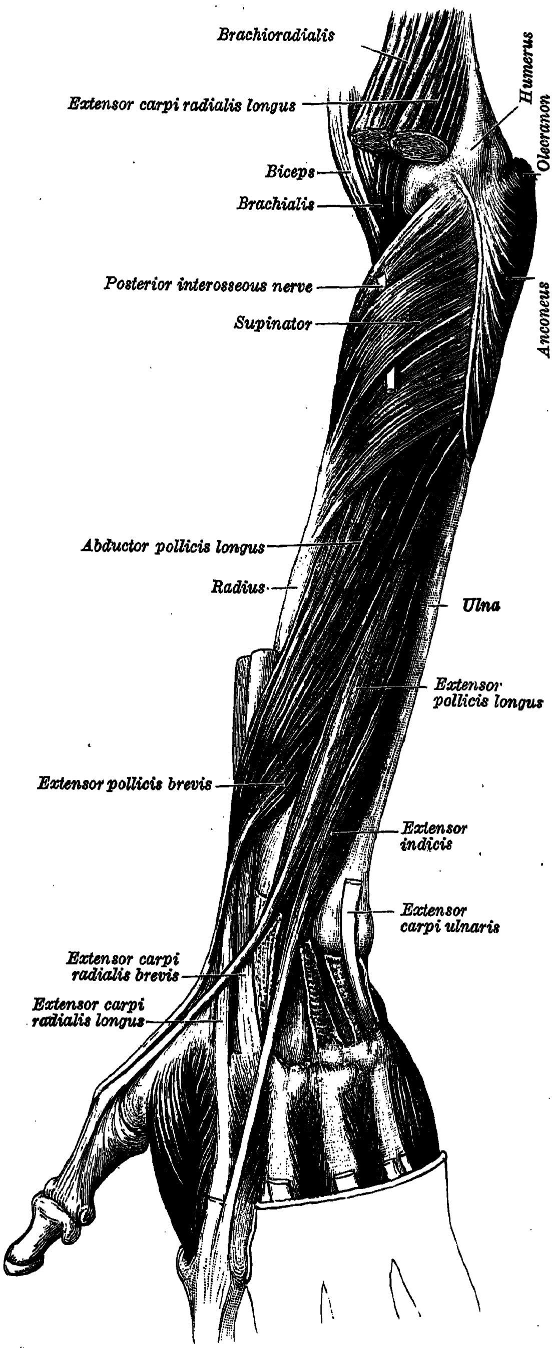
Action.—The Anconeus assists the Triceps in extending the elbow-joint.

(*b*) *Deep Group* (fig. 626)

Supinator. Extensor pollicis brevis.
Abductor pollicis longus. Extensor pollicis longus.
Extensor indicis.

The **Supinator** (figs. 621, 626, 627) surrounds the upper one-third of the radius, and consists of a superficial and a deep part, between which the posterior interosseous nerve (deep branch of the radial nerve) passes. The two parts arise in common—the superficial one by tendinous and the deeper by muscular fibres —from the lateral epicondyle of the humerus; from the lateral ligament of the elbow-joint, and the annular ligament of the superior radio-ulnar joint; from the supinator crest of the ulna and from the posterior part of the triangular depression in front of it; and from a tendinous expansion which covers the surface of the muscle. The muscle is inserted into the lateral surface of the proximal one-third of the radius, reaching as low as the insertion of the Pronator teres. The insertion extends on to the anterior and posterior aspects of the radius, for the anterior and posterior borders of the bone incline medially at their upper ends (p. 348) (fig. 412).

FIG. 626.—The left posterior antebrachial muscles. Deep group.



Nerve-supply.—The Supinator is supplied by the posterior interosseous nerve (C. 5 and 6).

Actions.—The Supinator rotates the radius so as to turn the palm of the hand forwards.

The **Abductor pollicis longus** (figs. 624, 625, 626) lies distal to the Supinator and is closely related to the Extensor pollicis brevis. It arises from the lateral part of the posterior surface of the shaft of the ulna below the insertion of the Anconeus, from the interosseous membrane, and from the middle one-third of the posterior surface of the shaft of the radius immediately adjoining the insertion of the supinator. Passing obliquely downwards and laterally, it ends in a tendon, (frequently two tendons),

which runs in a groove on the lateral side of the lower end of the radius, accompanied by the tendon of the Extensor pollicis brevis, and is inserted into the radial side of the base of the first metacarpal bone. It occasionally gives off two slips near its insertion: one to the trapezium (greater multangular bone), and the other to blend with the origin of the Abductor pollicis brevis.

Nerve-supply.—The Abductor pollicis longus is supplied by the posterior interosseous nerve (C. *6* and 7).

Actions.—The Abductor pollicis longus, acting with the Abductor pollicis brevis, abducts the thumb; acting with the Extensores pollicis, it extends the thumb at the carpometacarpal joint; acting with the Flexor carpi radialis and the corresponding extensors, it assists in abducting the hand, but it can only do so indirectly through the extended thumb.

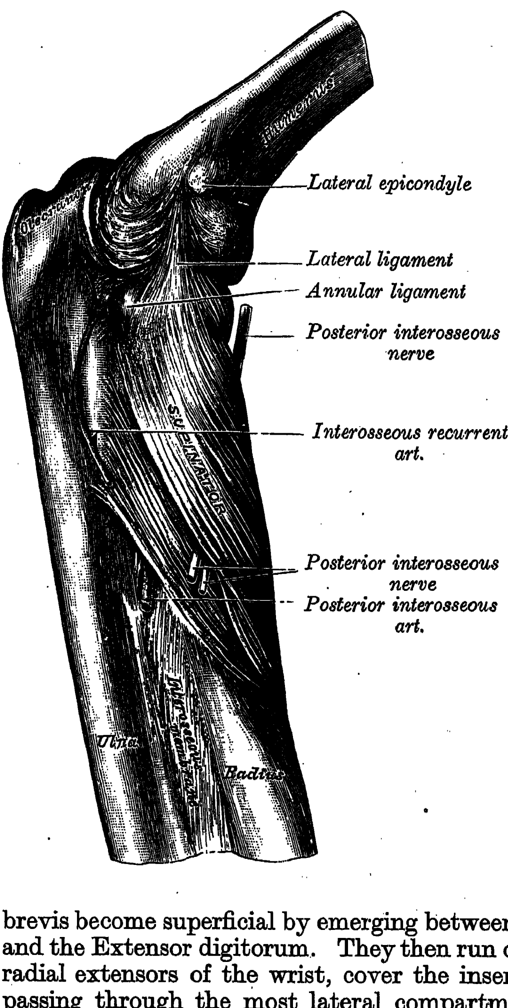


Fig. 627.—The right Supinator. Posterolateral aspect.

The **Extensor pollicis brevis** (figs. 625, 626) lies on the medial side of, and is closely connected with, the Abductor pollicis longus. It arises from the posterior surface of the shaft of the radius below that muscle, and from the interosseous membrane. Its direction is similar to that of the Abductor pollicis longus, its tendon passing through the same groove on the lateral side of the lower end of the radius, to be inserted into the dorsal surface of the base of the proximal phalanx of the thumb.

Nerve-supply.—The Extensor pollicis brevis is supplied by the posterior interosseous nerve (C. 7).

Actions.—The Extensor pollicis brevis extends the proximal phalanx of the thumb; when necessary, it can assist in extending the wrist and abducting the hand.

In the lower one-third of the forearm the Abductor pollicis longus and the Extensor pollicis brevis become superficial by emerging between the Extensor carpi radialis brevis and the Extensor digitorum. They then run obliquely across the tendons of the radial extensors of the wrist, cover the insertion of the Brachioradialis, and, passing through the most lateral compartment of the extensor retinaculum (dorsal carpal ligament), cross superficial to the styloid process of the radius and the radial artery.

The **Extensor pollicis longus** (figs. 625, 626) is larger than the Extensor pollicis brevis, the origin of which it partly covers. It arises from the lateral part of the middle one-third of the posterior surface of the shaft of the ulna below the origin of the Abductor pollicis longus, and from the interosseous membrane. It ends in a tendon, which passes through a compartment of the extensor retinaculum, lying in a narrow, oblique groove on the back of the lower end of the radius. It then crosses obliquely the tendons of the Extensores carpi radiales longus et brevis, and is separated from the Extensor pollicis brevis by a triangular interval, in which the radial artery lies; it is inserted into the base of the distal phalanx of the thumb.

Nerve-supply.—The Extensor pollicis longus is supplied by the posterior interosseous nerve (C. 7).

Actions.—The Extensor pollicis longus extends the distal phalanx of the thumb; it can assist, when required, in extending the wrist and abducting the hand.

The **Extensor indicis** (Extensor indicis proprius) (fig. 626) is a narrow, elongated muscle, medial to, and parallel with, the preceding. It arises from the posterior surface of the shaft of the ulna below the origin of the Extensor pollicis longus, and from the interosseous membrane. Its tendon passes under cover of the extensor retinaculum in the compartment which transmits the tendons of the Extensor digitorum; opposite the head of the second metacarpal bone it joins the ulnar side of the tendon of the Extensor digitorum which runs to the index finger.

Nerve-supply.—The Extensor indicis is supplied by the posterior interosseous nerve (C. 7).

Actions.—The Extensor indicis extends the index finger at the metacarpophalangeal joint, and can assist in extending the wrist.

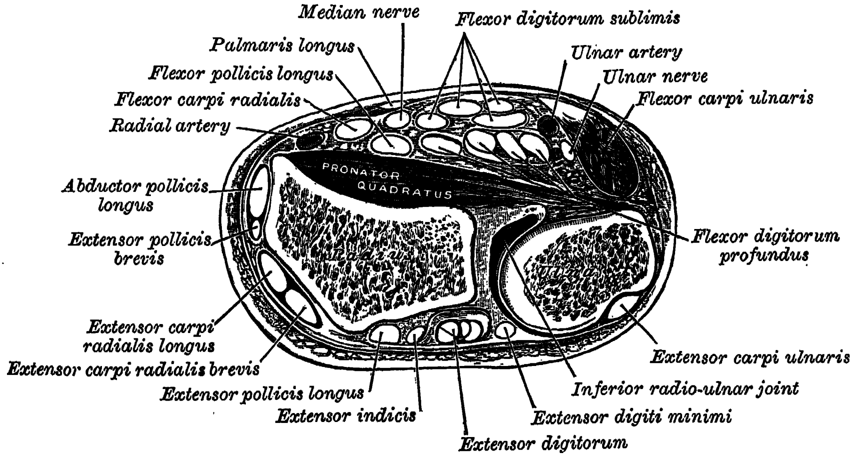
Applied Anatomy.—The tendons of the Abductor longus and extensors of the thumb are liable to become strained, and their sheaths inflamed (*tenosynovitis*) after excessive exercise, producing a sausage-shaped swelling along the course of the tendons and giving a peculiar grating sensation to the touch when the muscles are put in action.

Paralysis of the extensor muscles of the wrists and fingers resulting in 'wrist-drop' is common in lead poisoning in painters. The different extensor muscles are affected unequally as a rule. Thus the thumb, or index, or little finger may be but slightly implicated, and recover rapidly while the extensors of the other fingers or wrist remain powerless; and some of the flexor muscles of the fingers may become paretic. This apparently selective action of the lead in cases of lead poisoning depends in reality upon occupational over-use of the affected muscles or groups of muscles.

VI. The Muscles of the Hand

The muscles of the hand are subdivided into three groups: 1, those of the thumb, which occupy the lateral side and produce the *thenar* eminence; 2, those of the little finger, which occupy the medial side and give rise to the *hypothenar* eminence; 3, those in the middle of the palm and between the metacarpal bones.

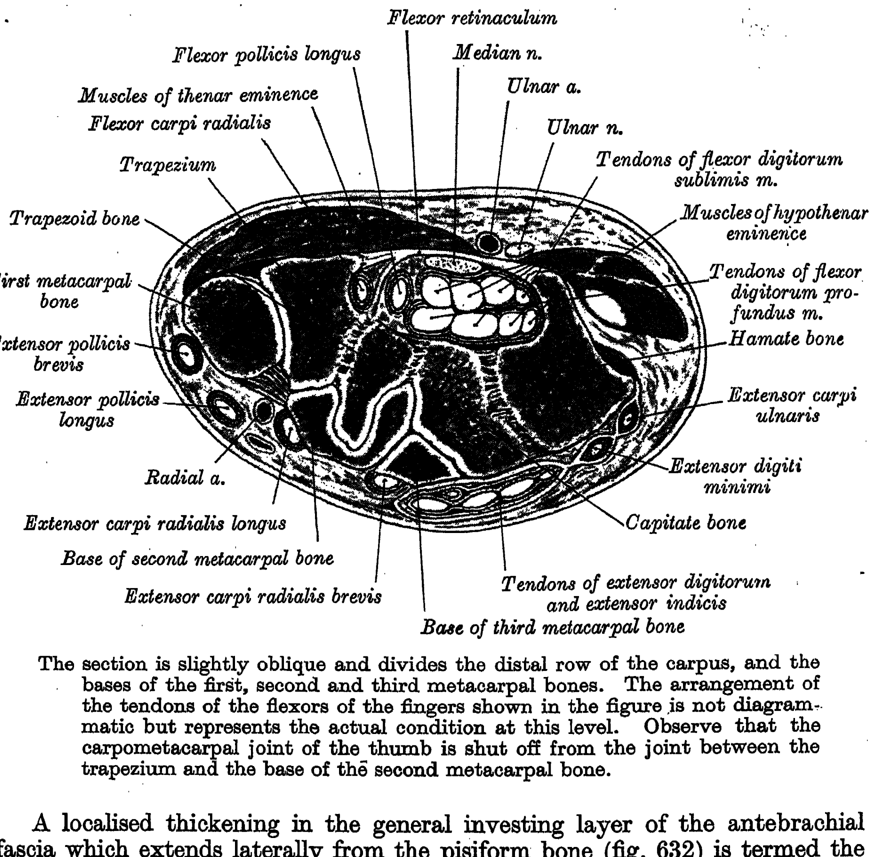
Fig. 628.—A transverse section through the distal ends of the left radius and ulna. Superior aspect.



The **flexor retinaculum** (transverse carpal ligament) (figs. 629, 630) is a strong, fibrous band which crosses the front of the carpus and converts the concavity formed by the anterior surfaces of the carpal bones into a tunnel, through which the flexor tendons of the digits and the median nerve pass. It is attached, medially, to the pisiform bone and to the hook of the hamate bone;

laterally, it splits into two laminæ, a superficial attached to the tubercle of the scaphoid (navicular) and the crest of the trapezium (greater multangular), and a deep, to the medial lip of the groove on the latter bone (fig. 629); the two laminæ form with the groove on the trapezium a tunnel, which is lined by a synovial sheath containing the tendon of the Flexor carpi radialis. The retinaculum is continuous, above, with the fascia covering the Flexor digitorum sublimis and with the general investing layer of the antebrachial fascia. It is these two layers which separate on reaching the trapezium. It is crossed superficially by the ulnar vessels and nerve, and the palmar cutaneous branches of the median and ulnar nerves. On its palmar surface the tendons of the Palmaris longus and Flexor carpi ulnaris are partly inserted; below, it gives origin to some of the short muscles of the thumb and little finger.

FIG. 629.—A transverse section through the left wrist, showing the tendons and their synovial sheaths.



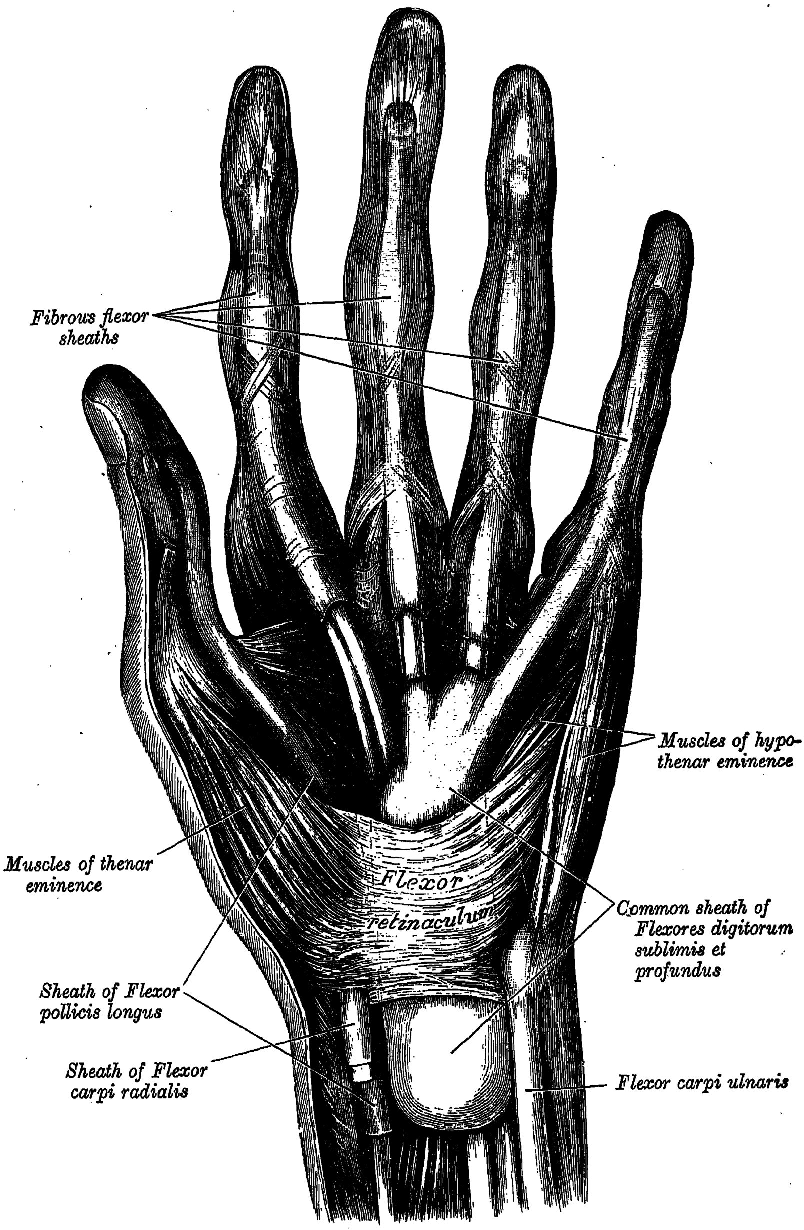
The section is slightly oblique and divides the distal row of the carpus, and the bases of the first, second and third metacarpal bones. The arrangement of the tendons of the flexors of the fingers shown in the figure is not diagrammatic but represents the actual condition at this level. Observe that the carpometacarpal joint of the thumb is shut off from the joint between the trapezium and the base of the second metacarpal bone.

A localised thickening in the general investing layer of the antebrachial fascia which extends laterally from the pisiform bone (fig. 632) is termed the *superficial part of the flexor retinaculum* (volar carpal ligament). It crosses in front of the ulnar vessels and nerves and blends with the rest of the retinaculum on their lateral side.

The synovial sheaths of the tendons on the front of the wrist.—Two synovial sheaths envelop the flexor tendons as they traverse the carpal tunnel, one for the Flexores digitorum sublimis et profundus, the other for the Flexor pollicis longus (fig. 630). These sheaths extend into the forearm for about 2·5 cm. above the flexor retinaculum, and occasionally communicate with each other behind that structure. The sheath of the Flexores digitorum tendons reaches about halfway along the metacarpal bones, where it ends in blind diverticula around the tendons to the index, middle, and ring fingers. It is prolonged on the tendons to the little finger and usually communicates with the digital synovial sheath of these tendons. A transverse section through the carpus (fig. 629) shows that the tendons have been invaginated into the sheath from

the lateral side. The parietal layer lines the flexor retinaculum and the floor of the carpal tunnel and is reflected, at the lateral side, on to the tendons of the flexor digitorum sublimis from in front, and on to those of the flexor digitorum profundus from behind. On the medial side a recess of the sheath is insinuated

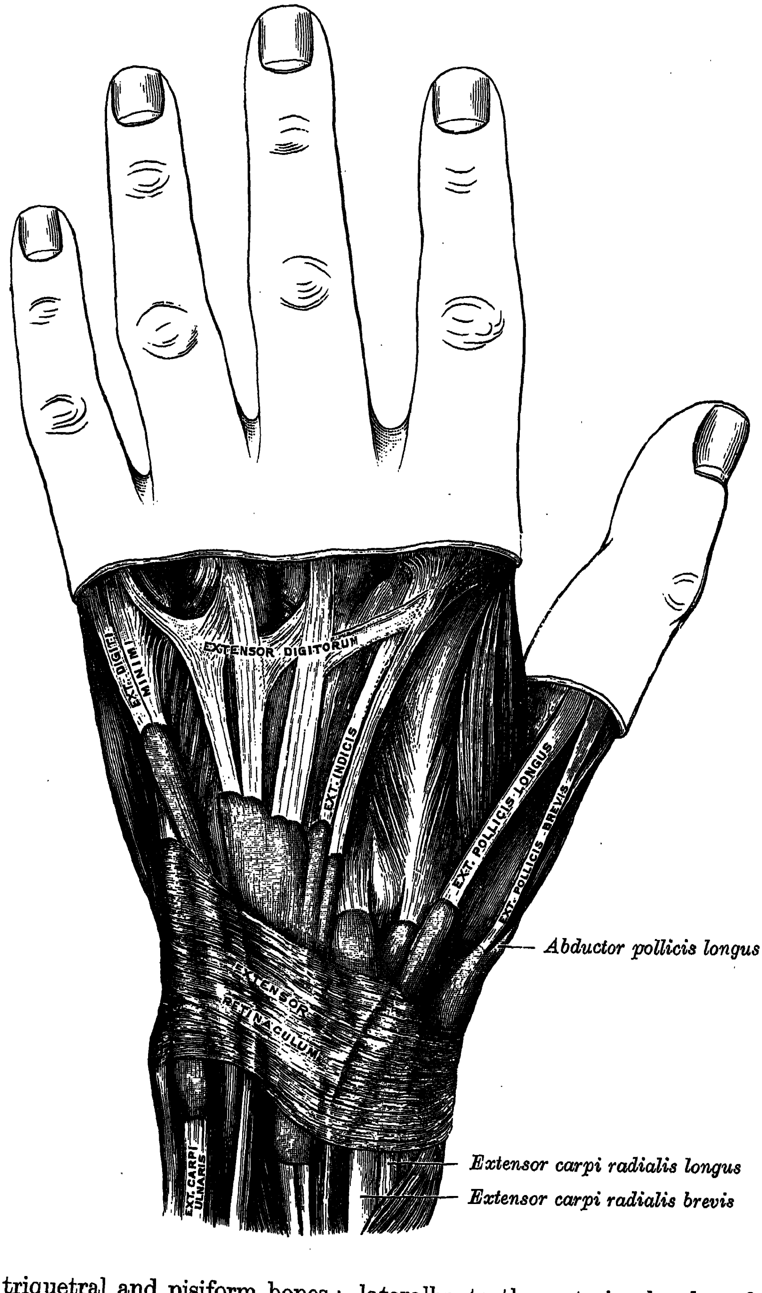
FIG. 630.—The synovial sheaths of the tendons on the front of the left wrist and hand. (From a specimen prepared by J. C. B. Grant.)



between the two groups of tendons for a variable distance. The sheath of the tendon of the Flexor pollicis longus, which may be separate or may communicate with the common flexor sheath behind the flexor retinaculum, is continued along the thumb as far as the insertion of the tendon. The fibrous sheaths enveloping the terminal parts of the tendons of the Flexores digitorum have already been described (p. 601).

The **extensor retinaculum** (dorsal carpal ligament) (fig. 631) is a strong, fibrous band, extending obliquely across the back of the wrist, and consisting of part of the antebrachial fascia, strengthened by the addition of some obliquely transverse fibres. It is attached, medially, to the styloid process of the ulna and

FIG. 631.—The synovial sheaths of the tendons on the back of the left wrist. (From a specimen prepared by J. C. B. Grant.)

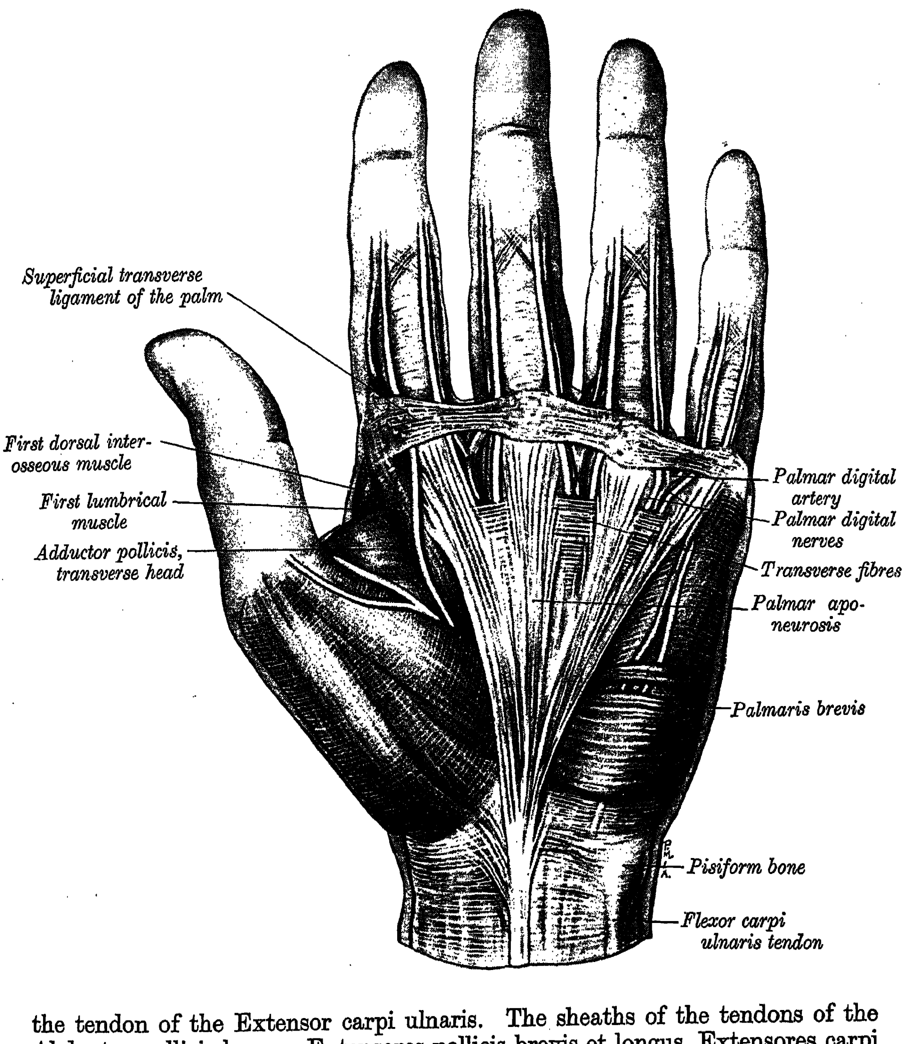


to the triquetral and pisiform bones; laterally, to the anterior border of the radius; and, in its passage across the wrist, to the ridges on the posterior surface of the radius.

The synovial sheaths of the tendons on the back of the wrist.—Deep to the extensor retinaculum there are six tunnels for the passage of the extensor tendons, each tunnel containing a synovial sheath. One is found in each

of the following positions (fig. 631): (1) on the lateral side of the styloid process of the radius, for the tendons of the Abductor pollicis longus and Extensor pollicis brevis; (2) behind the styloid process, for the tendons of the Extensores carpi radiales longus et brevis; (3) on the medial side of the dorsal tubercle of the radius, for the tendon of the Extensor pollicis longus; (4) on the medial side of the latter, for the tendons of the Extensor digitorum and Extensor indicis; (5) opposite the interval between the radius and ulna, for the Extensor digiti minimi; (6) between the head and the styloid process of the ulna, for

FIG. 632.—The left palmar aponeurosis.



the tendon of the Extensor carpi ulnaris. The sheaths of the tendons of the Abductor pollicis longus, Extensores pollicis brevis et longus, Extensores carpi radiales, and Extensor carpi ulnaris stop immediately proximal to the bases of the metacarpal bones, while those of the Extensor digitorum, Extensor indicis and Extensor digiti minimi are prolonged to the junction of the proximal with the intermediate one-third of the metacarpus.

The **palmar aponeurosis** (fig. 632) invests the muscles of the palm, and consists of central, lateral and medial portions.

The *central portion* occupies the middle of the palm, is triangular in shape, and of great strength and thickness. Its apex is continuous with the distal margin of the flexor retinaculum (transverse carpal ligament) and gives insertion to the expanded tendon of the Palmaris longus. Its base divides into four slips, one for each finger. The slips give off superficial fibres to the skin of the palm

and fingers ; those to the palm joining the skin at the furrow corresponding to the metacarpophalangeal joints, and those to the fingers passing into the skin at the transverse folds at the roots of the fingers. The deeper part of each slip subdivides into two processes which are inserted into the fibrous sheaths of the flexor tendons ; from the sides of these processes offsets are attached to the deep transverse ligaments of the palm (transverse metacarpal ligaments). By this arrangement short channels are formed on the front of the heads of the metacarpal bones ; through these the flexor tendons pass. The intervals between the four slips transmit the digital vessels and nerves, and the tendons of the Lumbrical muscles. At the points of division into the slips mentioned, numerous strong, transverse fibres bind the separate processes together. The central part of the palmar aponeurosis is intimately bound to the skin by dense fibro-areolar tissue, and the proximal part of its medial margin gives origin to the Palmaris brevis. It covers the superficial palmar arch, the tendons of the Flexores digitorum, the terminal part of the median nerve, and the superficial part of the ulnar nerve.

The *lateral* and *medial portions* of the palmar aponeurosis are thin, fibrous layers which cover the muscles of the ball of the thumb and the short muscles of the little finger respectively ; they are continuous with the central portion and with the fascia on the dorsum of the hand.

A septum passes dorsally from each border of the central portion of the palmar aponeurosis. The *medial palmar septum* lies close to the lateral side of the Opponens digiti minimi and reaches the palmar surface of the fifth metacarpal bone. At its distal end it is continuous with the slip of the palmar aponeurosis to the medial side of the fibrous sheath of the little finger ; at its proximal end it reaches the hook of the hamate bone and the pisohamate ligament and is pierced by the deep branches of the ulnar nerve and artery. The *lateral palmar septum* passes dorsally from the lateral border of the central portion of the palmar aponeurosis to reach the palmar surface of the first metacarpal bone. It lies along the medial side of the Flexor brevis and Opponens pollicis muscles ; intervening between them and the Flexor pollicis longus tendon and its synovial sheath. At its proximal end it reaches the crest of the trapezium and is pierced by the branch from the median nerve to the muscles of the thenar eminence.

The fascial spaces of the palm.—The central part of the palm, which lies behind the central portion of the palmar aponeurosis and between the lateral and medial palmar septa, is further subdivided into medial and lateral parts by an intermediate palmar septum. The medial area has been termed the *middle palmar space* (Kanavel) and the lateral area the *thenar space.*

The *intermediate palmar septum* lies between the flexor tendons of the index finger on the lateral side and the second lumbrical muscle on the medial side. At its distal end it is continuous with the slip given by the palmar aponeurosis to the medial side of the fibrous sheath of the index and the adjoining deep transverse ligament of the palm. Dorsally, it blends with the fasciæ covering the distal part of the second Palmar interosseous muscle and the transverse head of the Adductor pollicis, and it can be traced medially on the latter muscle to the third metacarpal bone. Anteriorly, it is attached to the deep surface of the palmar aponeurosis, but at its proximal end it meets the common flexor synovial sheath and blends with the connective tissue on its posterior surface.

The *middle palmar space* lies between the medial palmar septum and the intermediate septum. Its dorsal wall is formed by the third, fourth and fifth metacarpal bones, by the fascia covering the Interosseous muscles in the third and fourth spaces, and by the fascia covering the medial part of the transverse head of the Adductor pollicis. Its anterior wall is formed by the central portion of the palmar aponeurosis and, proximally, by the common flexor synovial sheath. The middle palmar space contains the flexor tendons of the fifth, fourth and third fingers, the fourth, third and second lumbrical muscles, the superficial palmar arch and the digital vessels and nerves for the fifth, fourth, third and ulnar side of the index finger. Distally, the space communicates with the subcutaneous tissues at the webs between the fingers : proximally, it may extend upwards dorsal to the common flexor synovial sheath.

The *thenar space* lies between the lateral and the intermediate palmar septum. Dorsally, it is bounded by the fasciæ covering the transverse head of the Adductor pollicis and, beyond its lower border, the first Dorsal interosseous muscle. Anteriorly, it is bounded by the palmar aponeurosis. It contains the Flexor pollicis longus tendon and its synovial sheath, the Flexor tendons of the index finger and the first Lumbrical muscle, and the

palmar digital vessels and nerves of the thumb and radial side of the index finger. Distally the space communicates with the subcutaneous tissues of the web of the thumb ; proximally it extends upwards behind the flexor retinaculum.

The **superficial transverse ligament of the palm** forms a thin band (fig. 632) which stretches across the roots of the fingers, and is attached to the skin of the clefts, and medially to the fifth metacarpal bone, forming a sort of rudimentary web. The digital vessels and nerves pass deep to these fasciculi.

Applied Anatomy.—The palmar aponeurosis is liable to undergo contraction, producing a very inconvenient deformity known as 'Dupuytren's contraction.' The ring and little fingers are most frequently implicated, but the others may also be involved. The proximal phalanx is flexed and cannot be straightened, and the middle and distal phalanges become similarly flexed as the disease advances.

Owing to their constant exposure to injury and septic influences, the fingers are very liable to become the seat of serious inflammatory mischief. In some cases, the inflammation may involve the sheath or theca of the flexor tendons, and may spread rapidly upwards along it ; but the extent will depend upon the particular digit involved. From the description of the flexor sheaths given above, it will be evident that inflammation of the synovial sheaths of the thumb and little finger may prove a far more formidable affection than that of the other three digits, because the sheaths of these two digits communicate with the large synovial sheath which surrounds the flexor tendons (p. 610), and the inflammation may extend into the palm of the hand and behind the flexor retinaculum into the forearm.

Chronic inflammation of the common flexor sheath is occasionally met with, constituting a disease known as *compound palmar ganglion* ; it presents an hour-glass outline, with a swelling in front of the wrist and another in the palm of the hand, and a constriction, corresponding to the flexor retinaculum, between the two. The fluid can be forced from the one swelling to the other under the retinaculum, and when this is done a creaking sensation is sometimes perceived, from the presence of 'melon-seed' bodies in the interior of the ganglion.

1. The Lateral Muscles of the Palm (figs. 633, 634, 635)

Abductor pollicis brevis.	Flexor pollicis brevis.
Opponens pollicis.	Adductor pollicis.

The **Abductor pollicis brevis** (fig. 635) is a thin, subcutaneous muscle which occupies the radial part of the thenar eminence ; its chief origin is from the flexor retinaculum (transverse carpal ligament), but a few fibres spring from the tubercle of the scaphoid bone and the crest of the trapezium and frequently some arise from the tendon of the Abductor pollicis longus (p. 607). It is inserted by a thin, flat tendon into the radial side of the base of the proximal phalanx of the thumb ; it also sends a slip to the tendon of the Extensor pollicis longus.

Nerve-supply.—The Abductor pollicis brevis is supplied by the lateral terminal branch of the median nerve.

Actions.—The Abductor pollicis brevis draws the thumb forwards in a plane at right angles to the palm of the hand. The movement occurs almost entirely at the carpometacarpal joint, but a minor degree of movement may occur at the metacarpophalangeal joint also.

The **Opponens pollicis** (figs. 633, 634) is placed under cover of the Abductor pollicis brevis. It arises from the crest on the trapezium and from the flexor retinaculum, and is inserted into the whole length of the lateral border, and the lateral one-half of the palmar surface, of the metacarpal bone of the thumb.

Nerve-supply.—The Opponens pollicis is supplied by the lateral terminal branch of the median nerve.

Actions.—The Opponens pollicis flexes the metacarpal bone of the thumb, i.e. bends it medially across the palm of the hand, and rotates it medially. By this combination, which is termed opposition, the palmar surface of the tip of the thumb can be brought into contact with the palmar surface of the tip of any of the fingers.

The **Flexor pollicis brevis** * (fig. 635) lies on the ulnar side of the Abductor pollicis brevis. It arises from the lower border of the flexor retinaculum and

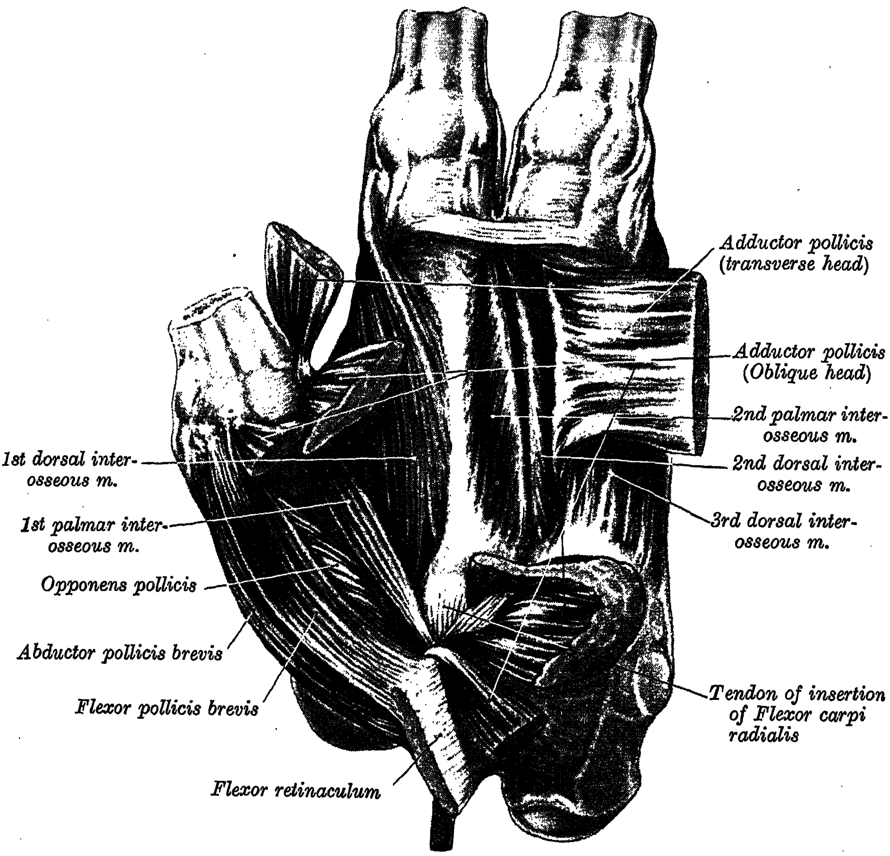
* In the B.N.A. the Flexor pollicis brevis has a deep head, which is now described as the first palmar interosseous muscle (p. 620).

the lower part of the crest on the trapezium ; it passes along the radial side of the tendon of the Flexor pollicis longus, and is inserted into the radial side of the base of the proximal phalanx of the thumb ; in its tendon of insertion there is a sesamoid bone. It is frequently more or less blended with the medial border of the opponens pollicis.

Nerve-supply.—The Flexor pollicis brevis is supplied by the lateral terminal branch of the median nerve.

Actions.—The Flexor pollicis brevis flexes the proximal phalanx of the thumb.

Fig. 633.—A dissection of the left hand to show the first palmar interosseous muscle (deep head of the Flexor pollicis brevis).



N.B.—The abductor and the flexor pollicis brevis have been displaced to the lateral side.

The **Adductor pollicis** (fig. 634) arises by two heads, an oblique and a transverse. The *oblique head* arises from the capitate and trapezoid (lesser multangular) bones, the bases of the second and third metacarpal bones, the palmar ligaments of the carpus and the sheath of the tendon of the Flexor carpi radialis. Most of its fibres converge to a tendon, which, uniting with the tendons of the first palmar interosseous muscle (deep portion of the Flexor pollicis brevis) and the transverse head of the Adductor, is inserted into the ulnar side of the base of the proximal phalanx of the thumb, a sesamoid bone being present in the tendon. A considerable fasciculus, however, passes deep to the tendon of the Flexor pollicis longus and joins the Flexor pollicis brevis and the Abductor pollicis brevis. The *transverse head* (fig. 634) is the most deeply seated of this group of muscles. It is of a triangular form, and arises from the distal two-thirds of the palmar surface of the third metacarpal bone ; the fibres converge

to be inserted, with the oblique head of the muscle and with the first palmar interosseous muscle, into the ulnar side of the base of the proximal phalanx of the thumb.

Nerve-supply.—The Adductor pollicis is supplied by the deep branch of the ulnar nerve.

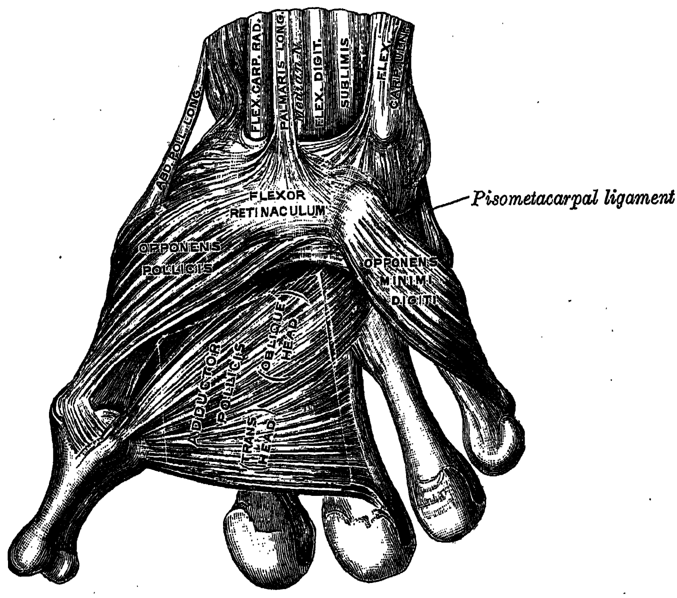
Action.—The Adductor pollicis approximates the thumb to the palm of the hand.

2. The Medial Muscles of the Palm (figs. 634, 635)

Palmaris brevis.	Flexor digiti minimi.
Abductor digiti minimi.	Opponens digiti minimi.

The **Palmaris brevis** (fig. 632) is a thin, quadrilateral muscle, placed beneath the skin of the ulnar side of the hand. It arises from the flexor retinaculum and from the medial border of the central part of the palmar aponeurosis; it is inserted into the skin on the ulnar border of the hand. It covers the ulnar artery and the superficial terminal branch of the ulnar nerve.

Fig. 634.—The right Opponens pollicis, Adductor pollicis and Opponens digiti minimi.



Nerve-supply.—The Palmaris brevis is supplied by the superficial branch of the ulnar nerve.

Action.—The Palmaris brevis wrinkles the skin on the ulnar side of the palm of the hand and deepens the hollow of the palm by accentuating the prominence of the hypothenar eminence. In this way it contributes to the security of the palmar grip.*

The **Abductor digiti minimi** (fig. 635) is situated on the ulnar border of the palm of the hand. It arises from the pisiform bone, from the tendon of the Flexor carpi ulnaris and from the pisohamate ligament. It ends in a flat tendon which divides into two slips; one is inserted into the ulnar side of the base of the proximal phalanx of the little finger, the other into the ulnar border of the aponeurosis of the Extensor digiti minimi.

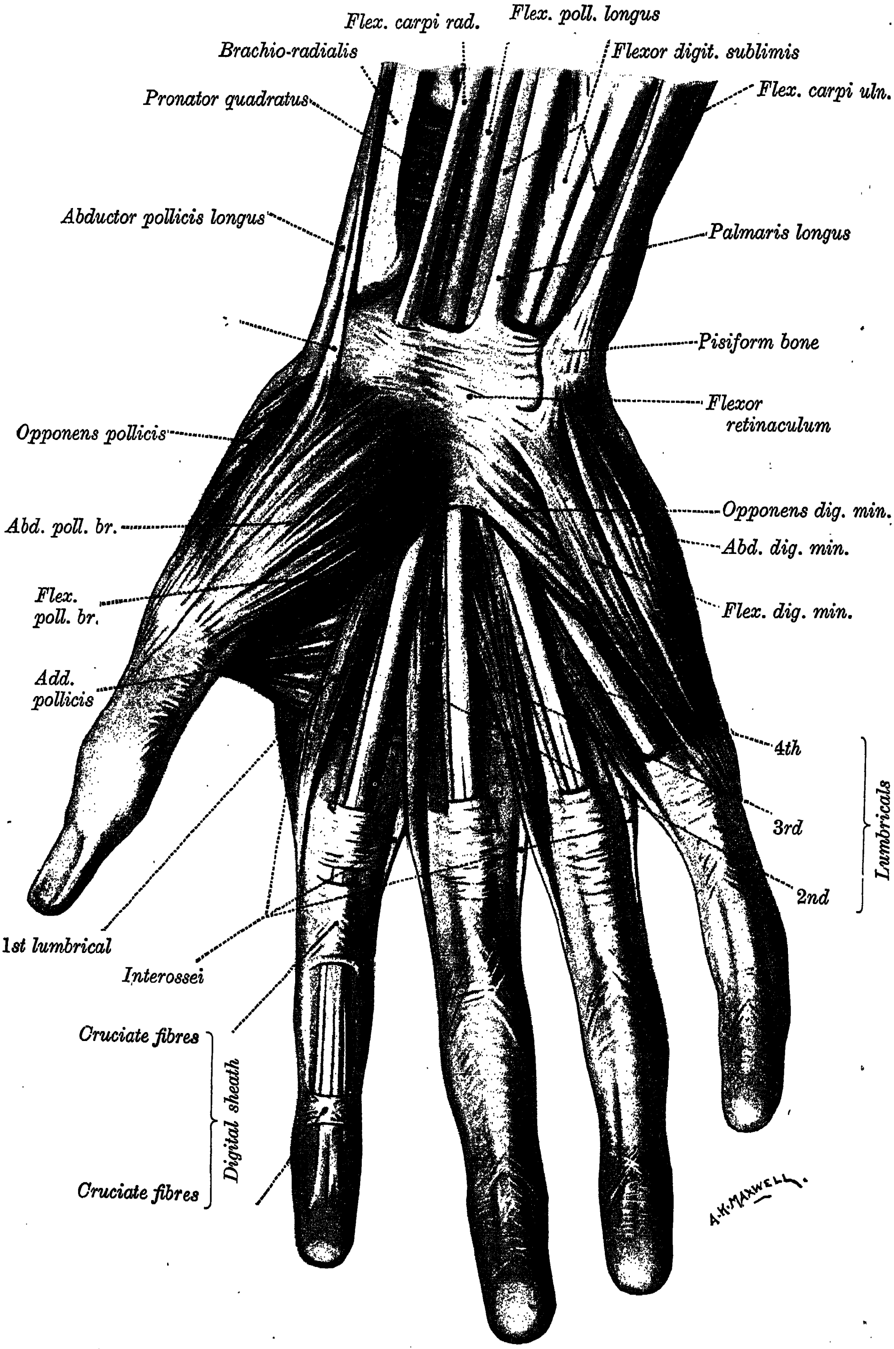
Action.—The Abductor digiti minimi abducts the proximal phalanx of the little finger.

The **Flexor digiti minimi** (Flexor digiti quinti brevis) (fig. 635) lies on the radial side of the preceding muscle. It arises from the convex surface of the hook of the hamate bone and the palmar surface of the flexor retinaculum, and is inserted into the ulnar side of the base of the proximal phalanx of the little

* T. S. Kirk, *Journal of Anatomy*, vol. 58.

finger with the Abductor digiti minimi. Its origin is separated from that of the Abductor by the deep branches of the ulnar artery and nerve. This muscle may be wanting, or may be used with the Abductor.

Fig. 635.—Superficial dissection of muscles of the palm of the hand. (From Quain's *Anatomy,* XI. Edition.)



* An accessory slip frequently present connecting the long and short abductors of the thumb.

Actions.—The Flexor digiti minimi flexes the proximal phalanx of the little finger.

The **Opponens digiti minimi** (fig. 634) is of a triangular form, and placed under cover of the Flexor and Abductor. It arises from the convexity of the

hook of the hamate bone, and contiguous portion of the flexor retinaculum ; it is inserted into the whole length of the ulnar margin of the fifth metacarpal bone.

Action.—The Opponens digiti minimi draws the fifth metacarpal bone forwards and laterally, so as to deepen the hollow of the palm.

Nerve-supply.—All the muscles of the little finger are supplied by the deep branch of the ulnar nerve.

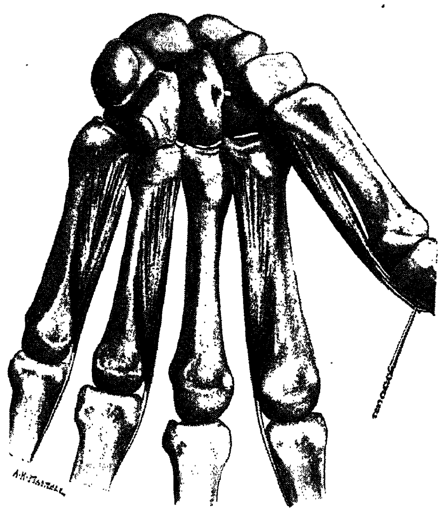
3. The Intermediate Muscles

Lumbricales. Interossei.

The **Lumbricales** (fig. 635) are four small fleshy fasciculi which take origin from the tendons of the Flexor digitorum profundus. The first and second arise from the radial sides and palmar surfaces of the tendons of the index and middle fingers respectively ; the third, from the contiguous sides of the tendons of the middle and ring fingers ; and the fourth, from the contiguous sides of

Fig. 636.—The Dorsal interosseous muscles of the left hand. Viewed from in front.

Fig. 637.—The Palmar interosseous muscles of the left hand. Viewed from in front.



the tendons of the ring and little fingers. Each passes to the radial side of the corresponding finger, and is inserted partly into the base of the proximal phalanx, but mainly into the lateral margin of the tendinous expansion of the Extensor digitorum covering the dorsal surface of the finger.

Nerve-supply.—The first and second Lumbricals are supplied by the median nerve ; the third and fourth Lumbricals by the deep terminal branch of the ulnar nerve. The third Lumbrical frequently receives a twig from the median nerve.

Actions.—The Lumbricals flex the proximal and extend the middle and distal phalanges, a combination of movements which is called for in the upstroke in writing, etc.

The **Interossei** occupy the intervals between the metacarpal bones, and are divided into a dorsal and a palmar set.

The **Interossei dorsales** (fig. 636), four in number, are bipennate muscles, each arising by two heads from the adjacent sides of the metacarpal bones, but more extensively from the metacarpal bone of the finger into which the muscle is inserted. They are inserted into the bases of the proximal phalanges and into the aponeuroses of the tendons of the Extensor digitorum. Between the double origin of each of these muscles there is a narrow triangular interval ; through the first of these intervals the radial artery passes ; through each of the others a perforating branch from the deep palmar arch is transmitted.

The *first*, and largest, is sometimes named the *Abductor indicis*; it is inserted into the radial side of the index finger. The *second* and *third* are inserted into the middle finger, the former into its radial, the latter into its ulnar side. The *fourth* is inserted into the ulnar side of the ring finger.

The **Interossei palmares** (fig. 637), four in number, are smaller than the dorsal interossei, and are placed upon the palmar surfaces of the metacarpal bones, rather than between them. With the exception of the first, each arises from the entire length of the metacarpal bone of one finger, and is inserted into the side of the base of the proximal phalanx of the same finger, and into the aponeurosis of the Extensor digitorum tendon.

The *first* (formerly known as the 'deep head of the Flexor pollicis brevis') arises from the ulnar side of the palmar surface of the base of the first metacarpal bone (fig. 633), and is inserted into the ulnar side of the base of the proximal phalanx of the thumb, in common with the principal part of the oblique head of the Adductor pollicis. It lies in front of the lateral head of the first Dorsal interosseous muscle, and is covered by the oblique head of the Adductor pollicis. The *second* arises from the ulnar side of the second metacarpal bone, and is inserted into the same side of the proximal phalanx of the index finger. The *third* arises from the radial side of the fourth metacarpal bone, and is inserted into the same side of the ring finger. The *fourth* arises from the radial side of the fifth metacarpal bone, and is inserted into the same side of the little finger. From this account it may be seen that each finger is provided with a pair of Interosseous muscles, with the exception of the little finger, in which the Abductor digiti minimi takes the place of one of the pair.

Nerve-supply.—Both dorsal and palmar interossei are supplied by the deep branch of the ulnar nerve.

Actions.—The dorsal interossei abduct the fingers (p. 478) from an imaginary line drawn longitudinally through the centre of the middle finger; and the palmar interossei adduct the fingers to that line. The Interossei, in conjunction with the Lumbricals, flex the proximal phalanges, and, in consequence of their insertions into the expansions of the Extensor tendons, extend the middle and distal phalanges. The first Palmar interosseous flexes the proximal phalanx of the thumb.

Segmental Innervation of the Muscles of the Hand

Clinical observations indicate that all the small muscles of the hand receive their motor innervation from T. 1.

THE FASCIÆ AND MUSCLES OF THE LOWER LIMB

The muscles of the lower limb are subdivided into groups corresponding with the different regions of the limb.

I. Muscles of the iliac region.
II. Muscles of the thigh.
III. Muscles of the leg.
IV. Muscles of the foot.

I. The Muscles of the Iliac Region (fig. 638)

Psoas major. Psoas minor. Iliacus.

The **fascia iliaca** covers the Psoas and Iliacus. It is thin above, but becomes gradually thicker as it approaches the inguinal ligament.

The *portion covering the Psoas* is thickened above to form the medial arcuate ligament (medial lumbocostal arch), which stretches from the transverse process of the first to the body of the first or second lumbar vertebra. Medially, the fascia covering the Psoas is attached by a series of arched processes to the intervertebral discs, and prominent margins of the bodies of the vertebræ, and to the upper part of the sacrum. Laterally, above the crest of the ilium, it blends with the fascia covering the front of the Quadratus lumborum (p. 572): below the crest, with the fascia covering the Iliacus.

The *portion covering the Iliacus* is connected, laterally, to the whole length of the inner lip of the iliac crest; and medially, to the brim of the true pelvis, where it blends with the periosteum. It is attached to the iliopubic (iliopectineal) eminence and there receives a slip from the tendon of insertion of the Psoas minor, when that muscle exists. The external iliac vessels lie in front of the fascia but the branches of the lumbar plexus of nerves are behind it; it is separated from the peritoneum by the extraperitoneal tissue.

Lateral to the femoral vessels, the iliac fascia is intimately connected to the posterior margin of the inguinal ligament, and is there continuous with the transversalis fascia. It passes behind the femoral vessels, and beyond the inguinal ligament becomes the *iliopectineal fascia*. This fascia divides the space between the inguinal ligament and the hip-bone into a medial and a lateral part; the medial part transmits the femoral vessels, the lateral the Psoas major, the Iliacus and the femoral nerve. Medial to the vessels, the iliopectineal fascia is attached to the pectineal line of the pubis and is continuous with the pectineal fascia. In the thigh the iliopectineal fascia covers the Iliacus and the Psoas major, and forms the posterior wall of the femoral sheath.

The **Psoas major** (fig. 638) is a long fusiform muscle placed on the side of the lumbar region of the vertebral column and the brim of the true pelvis. It arises (1) from the anterior surfaces and lower borders of the transverse processes of all the lumbar vertebræ; (2) by five slips or digitations, each of which takes origin from the bodies of two vertebræ and their intervertebral disc; the highest slip arises from the lower margin of the body of the twelfth thoracic vertebra, the upper margin of the body of the first lumbar vertebra and the interposed disc, the lowest slip from the adjacent margins of the bodies of the fourth and fifth lumbar vertebræ and the interposed disc; (3) from a series of tendinous arches extending across the constricted parts of the bodies of the lumbar vertebræ between the preceding slips; the lumbar arteries and veins, and filaments from the sympathetic trunk, pass deep to these arches. The muscle proceeds downwards across the brim of the true pelvis, passes behind the inguinal ligament and in front of the capsule of the hip-joint, and ends in a tendon. The latter receives nearly the whole of the fibres of the Iliacus and is inserted into the lesser trochanter of the femur. A large bursa, which occasionally communicates with the cavity of the hip-joint, separates the tendon from the pubis and the capsule of the joint.

Relations.—The uppermost part of the Psoas major lies behind the diaphragm and occupies the lowest part of the posterior mediastinum. It may be in contact with the posterior, lower limit of the pleural sac. In the abdomen the Psoas major is in relation by its *anterolateral surface* with the medial arcuate ligament (medial lumbocostal arch), the fascia covering the muscle, the extraperitoneal tissue and peritoneum, the kidney, Psoas minor, renal vessels, ureter, testicular (or ovarian) vessels, and genitofemoral nerve. In front the right Psoas is overlapped by the inferior vena cava and crossed by the terminal portion of the ileum, and the left is crossed by the colon. Its *posterior surface* is in relation with the transverse processes of the lumbar vertebræ, and the medial edge of the Quadratus lumborum. The lumbar plexus is situated in the posterior part of the substance of the muscle. *Medially*, the muscle is in relation with the bodies of the lumbar vertebræ and the lumbar vessels. Along its anterior (or medial) margin the muscle is in relation with the sympathetic trunk, and the aortic lymph-glands and, along the brim of the pelvis, with the external iliac artery. This margin is covered by the inferior vena cava on the right side, and on the left side lies posterior and lateral to the abdominal aorta.

In the thigh it is in relation, *in front*, with the fascia lata and the femoral artery; *behind*, with the capsule of the hip-joint, from which it is separated by a bursa; by its *medial border*, with the Pectineus and medial circumflex femoral artery, and also with the femoral vein, which may overlap it slightly; by its *lateral border*, with the femoral nerve and the Iliacus.

The femoral nerve descends at first through the fibres of Psoas major, and then lies between it and the Iliacus.

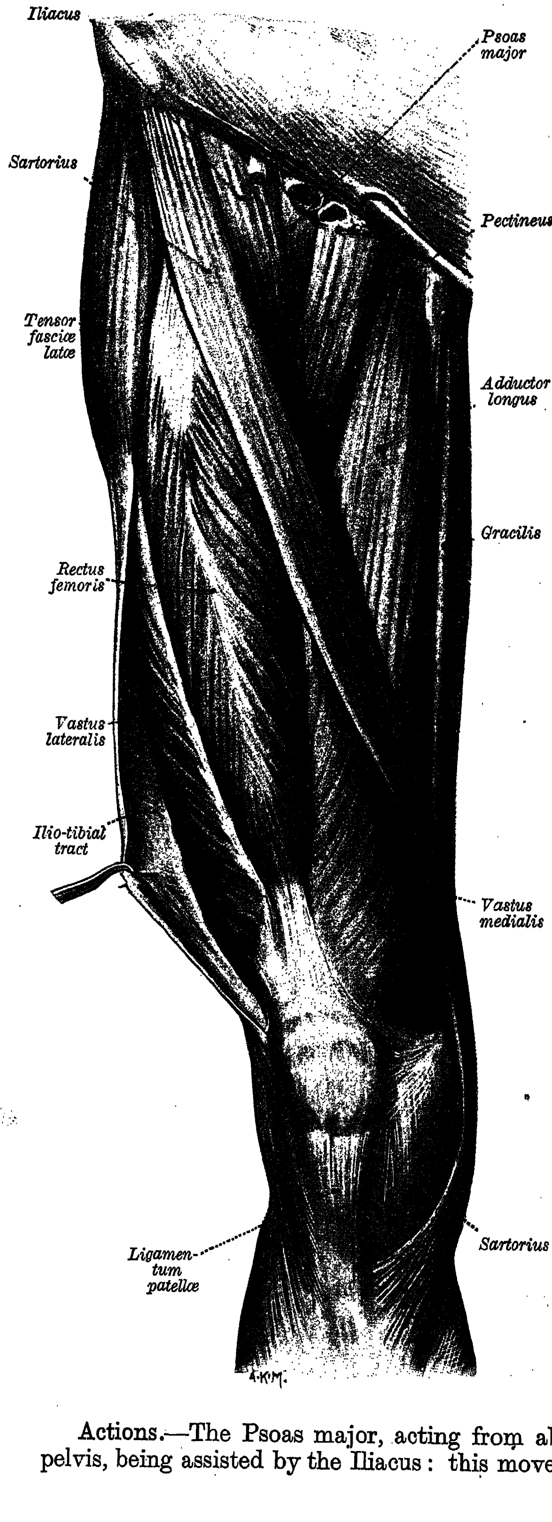
Nerve-supply.—The Psoas major is supplied by branches from the second and third lumbar nerves.

Actions.—The Psoas major acts conjointly with the Iliacus (p. 622).

The **Psoas minor** (fig. 638) is placed in front of the Psoas major within the abdomen. It arises from the sides of the bodies of the twelfth thoracic and first

lumbar vertebræ and from the disc between them. It ends in a long, flat tendon which is inserted into the pectineal line and iliopubic eminence, and, by its lateral border, into the iliac fascia. This muscle is absent in about 40 per cent. of subjects.

FIG. 638.—Muscles on the front of the thigh, superficial dissection. (From Quain's *Anatomy*, XI. Edition.)



Nerve-supply.—The Psoas minor is supplied by a branch from the first lumbar nerve.

Action.—The Psoas minor is a tensor of the iliac fascia and a weak flexor of the trunk.

The **Iliacus** (fig. 638) is a flat, triangular muscle which fills the iliac fossa. It arises from the upper two-thirds of the iliac fossa, from the inner lip of the iliac crest, from the anterior sacro-iliac and ilio-lumbar ligaments, and from the upper surface of the lateral mass of the sacrum (fig. 276); in front, it reaches as far as the anterior superior and anterior inferior iliac spines, and receives a few fibres from the upper part of the capsular ligament of the hip-joint. Most of its fibres converge to be inserted into the lateral side of the tendon of the Psoas major, but some of them are attached to the shaft of the femur for 2·5 cm. below and in front of the lesser trochanter.

Relations.—Within the abdomen, the Iliacus is in relation, by its *anterior surface*, with the iliac fascia, which separates the muscle from the extraperitoneal tissue and peritoneum, and with the lateral femoral cutaneous nerve; on the right side, with the cæcum; on the left side, with the iliac part of the descending colon; by its *posterior surface*, with the iliac fossa; by its *medial border*, with the Psoas major and femoral nerve.

In the thigh, it is in relation, by its *anterior surface*, with the fascia lata, Rectus femoris, Sartorius and arteria profunda femoris; by its *posterior surface*, with the capsule of the hip-joint, a bursa common to it and the Psoas major being interposed.

Nerve-supply.—The Iliacus is supplied by branches of the femoral nerve (L. 2 and 3).

Actions.—The Psoas major, acting from above, flexes the thigh upon the pelvis, being assisted by the Iliacus: this movement imposes a slight degree of

medial rotation on the femur; acting from below, with the femur fixed, the Psoas major bends the lumbar portion of the vertebral column forwards and to its own side, and then, in conjunction with the Iliacus, tilts the pelvis forwards. When the Psoas major and Iliacus of both sides act from below, they serve to maintain the erect posture by supporting the vertebral column and pelvis upon the femora, or in continued action bend the trunk and pelvis forwards, as in raising the trunk from the recumbent posture.

Applied Anatomy.—When an abscess forms beneath the fascia covering the Psoas and Iliacus, as often happens, the pus is contained in an osseofibrous cavity which is closed on all sides within the abdomen, and is open only at its lower part, where the fascia is prolonged over the muscles into the thigh. When the disease is in the thoracic vertebræ, the pus tracks down the posterior mediastinum in front of the bodies of the vertebræ, and, passing behind the medial arcuate ligament, enters the sheath of the Psoas, down which it travels as far as the pelvic brim; it then passes deep to the iliac portion of the fascia, and fills up the iliac fossa. In consequence of the attachment of the fascia to the arcuate line (linea terminalis), it rarely finds its way into the true pelvis, but passes by a narrow opening behind the inguinal ligament into the thigh, lateral to the femoral vessels. When the lumbar vertebræ are the seat of the disease, the pus finds its way directly into the substance of the Psoas. The muscular fibres are destroyed, and the nerves contained in the abscess are isolated and exposed in its interior; the iliac vessels, which lie in front of the fascia, remain intact, and the peritoneum seldom becomes implicated. All psoas abscesses do not, however, pursue this course; the pus may leave the sheath of the muscle above the crest of the ilium, and tracking backwards may point in the loin (*lumbar abscess*); or it may point above the inguinal ligament in the inguinal region; or it may follow the course of the branches of the internal iliac vessels into the true pelvis, and, passing through the greater sciatic foramen into the gluteal region, may discharge itself on the back of the thigh.

II. The Muscles of the Thigh

1. The Anterior Femoral Muscles (fig. 638)

Tensor fasciæ latæ.	Quadriceps femoris	Rectus femoris.
Sartorius.		Vastus lateralis.
		Vastus medialis.
		Vastus intermedius.

Articularis genus.

The **superficial fascia** forms a continuous layer over the whole of the thigh; it consists of areolar tissue containing much fat in its meshes, and may be separated into two or more layers, between which the superficial vessels and nerves are found. It varies in thickness in different parts of the limb; in the groin it is thick, and the two layers are separated from each other by the superficial inguinal lymph-glands, the long saphenous vein and several smaller vessels. The superficial layer is continuous above with the superficial fascia of the abdomen. The deep layer of the superficial fascia is a very thin, fibrous stratum, best marked on the medial side of the long saphenous vein and below the inguinal ligament. It is placed behind the subcutaneous vessels and nerves and upon the surface of the fascia lata. It is intimately adherent to the fascia lata a little below the inguinal ligament. It covers the saphenous opening (fossa ovalis), being closely united to its circumference, and is connected to the sheath of the femoral vessels. The portion covering the opening is perforated by the long saphenous vein, small blood-vessels and lymph-vessels, hence it has been termed the *cribriform fascia*, the openings for these vessels having been likened to the holes in a sieve. A large subcutaneous bursa is found in the superficial fascia over the patella.

The **deep fascia** of the thigh is named, from its great extent, the *fascia lata* (fig. 639); it invests the whole of this region of the limb, but varies in thickness in different parts. Thus, it is thicker in the upper and lateral parts of the thigh, where it receives a fibrous expansion from the Gluteus maximus and where the Tensor fasciæ latæ is inserted between its layers; it is very thin behind and at the upper and medial parts, where it covers the Adductor muscles, but

becomes stronger around the knee, where it receives fibrous expansions from the tendon of the Biceps femoris laterally, from the Sartorius medially, and from the Quadriceps femoris in front. The fascia lata is attached, above and behind, to the back of the sacrum and coccyx; laterally, to the iliac crest; in front, to the inguinal ligament and to the superior ramus of the pubis; and medially, to the inferior ramus of the pubis, to the ramus and tuberosity of the ischium, and to the lower border of the sacrotuberous ligament. From its attachment to the iliac crest it descends as a dense fascia over the Gluteus medius to the upper border of the Gluteus maximus, where it splits into two layers, one passing superficial and the other deep to this muscle; at the lower border of the muscle the two layers reunite. Over the lateral surface of the thigh the fascia lata is specially thickened and forms a strong band which is termed the *iliotibial tract*. At its upper limit, where it splits into two layers, the tract receives the insertion of the Tensor fasciæ latæ and, posteriorly, it receives the insertion of the greater part of the tendon of the Gluteus maximus. Of the two layers the more superficial ascends on the lateral surface of the Tensor fasciæ latæ to reach the iliac crest; the deeper layer passes upwards and medially, under cover of the muscle, and blends with the lateral part of the capsule of the hip-joint. At its lower limit the iliotibial tract is attached to the lateral condyle of the tibia, but in this situation it is intimately blended with an aponeurotic expansion from the Vastus lateralis. Below, the fascia lata is attached to all the prominent points around the knee-joint, viz. the condyles of the femur and tibia, and the head of the fibula. On each side of the patella it is strengthened by transverse fibres from the lower parts of the Vasti, which are attached to and support this bone; of these fibres the lateral are the stronger and are continuous with the iliotibial tract. The fascia lata gives off two intermuscular septa, which are attached to the whole length of the linea aspera of the femur and its prolongations above and below: the lateral and stronger septum, which extends from the insertion of the Gluteus maximus to the lateral condyle, separates the Vastus lateralis in front from the short head of the Biceps femoris behind, and gives partial origin to these muscles; the medial and thinner septum separates the Vastus medialis from the Adductors and the Pectineus. Besides these there are numerous smaller septa, separating the individual muscles and enclosing each in a distinct sheath.

The saphenous opening (fossa ovalis) (fig. 639).—At the upper and medial part of the thigh, a little below the medial end of the inguinal ligament, the fascia lata presents a large oval aperture; it transmits the long saphenous vein and other smaller vessels, and is termed the *saphenous opening*. The cribriform fascia, which is pierced by the structures passing through the opening, covers the aperture and must be removed to expose it. The fascia lata in this part of the thigh is described as consisting of a superficial and a deep portion.

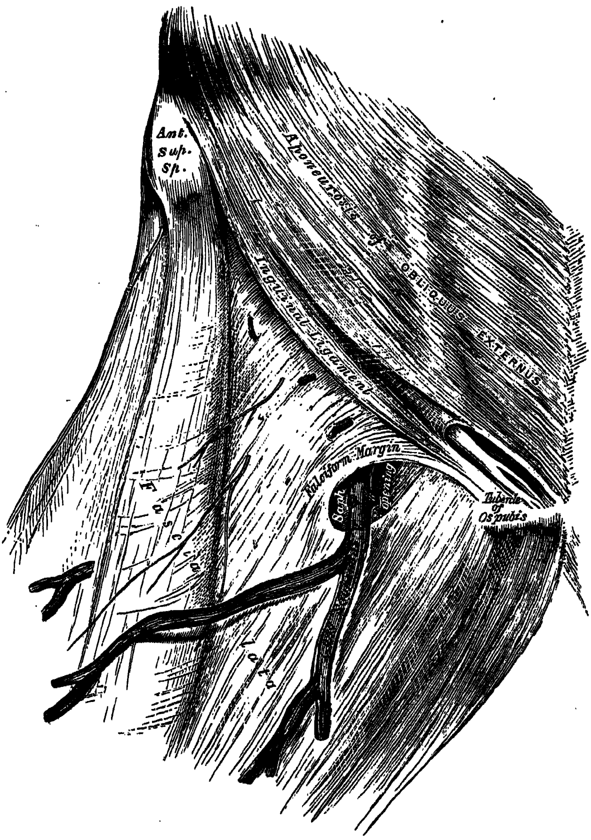
The *superficial portion* of the fascia lata is the part on the lateral side of the saphenous opening. It is attached to the crest and anterior superior spine of the ilium, to the whole length of the inguinal ligament, and to the pectineal line of the pubis (pecten pubis) in conjunction with the pectineal part of the inguinal ligament (lacunar ligament). From the pubic tubercle it is reflected downwards and laterally, as the arched *falciform margin*, which forms the anterior, lateral and lower boundaries of the saphenous opening (fig. 639); this margin overlies and is adherent to the anterior layer of the sheath of the femoral vessels, and the cribriform fascia is attached to it. The upward and medial prolongation of the falciform margin is named the *superior cornu*; its downward and medial prolongation, the *inferior cornu*. The latter is well defined, and is continuous behind the long saphenous vein with the deep portion of the fascia.

The *deep portion* is situated on the medial side of the saphenous opening, and is continuous with the superficial portion at the lower margin of the fossa; traced upwards, it covers the Pectineus, Adductor longus and Gracilis, and, passing behind the sheath of the femoral vessels, to which it is closely united, is continuous with the iliopectineal fascia, and is attached to the pectineal line of the pubis.

From this description it may be observed that the superficial portion of the fascia lata lies in front of the femoral vessels, and the deep portion behind them, so that an apparent aperture (the saphenous opening) exists between the two.

The **Tensor fasciæ latæ** (fig. 638) arises from the anterior 5 cm. of the outer lip of the iliac crest; from the outer surface of the anterior superior iliac spine, and part of the outer border of the notch below it, between the Gluteus medius and Sartorius; and from the deep surface of the fascia lata. It is inserted between the two layers of the iliotibial tract of the fascia lata about the junction of the middle with the upper one-third of the thigh.

FIG. 639.—The right saphenous opening (fossa ovalis).



Nerve-supply.—The Tensor fasciæ latæ is supplied by the superior gluteal nerve (L. 4 and 5 and S. 1).

Actions.—The Tensor fasciæ latæ tightens the fascia lata and so assists in extension of the knee; it assists also in abduction and in medial rotation of the thigh. In the erect posture, acting from below, it serves to steady the pelvis on the head of the femur; through the iliotibial tract it steadies the condyles of the femur on the tibia and helps to maintain the erect attitude by keeping the knee extended.

The **Sartorius** (figs. 638, 640, 642), which is the longest muscle in the body, is narrow and ribbon-like; it arises by tendinous fibres from the anterior superior iliac spine and the upper one-half of the notch below it. It crosses the upper and anterior parts of the thigh obliquely, from the lateral to the medial side, then descends vertically as far as the medial side of the knee, where a thin, flattened tendon replaces the fleshy belly. This tendon curves obliquely forwards and expands into a broad aponeurosis which is inserted, in front of the Gracilis and Semitendinosus, into the upper part of the medial surface of the shaft of the tibia (fig. 468). The upper part of the aponeurosis is curved backwards over

the upper edge of the tendon of the Gracilis so as to be inserted behind it. An offset, from its upper margin, blends with the capsule of the knee-joint, and another, from its lower border, with the fascia on the medial side of the leg.

The relations of this muscle to the femoral artery are important, as it constitutes the chief guide in tying the vessel. In the upper one-third of the thigh it forms the lateral side of the *femoral triangle*, the medial side of which is formed by the medial border of the Adductor longus, and the base by the inguinal ligament; the femoral artery passes through the middle of this triangle from its base to its apex. In the middle one-third of the thigh, the femoral artery is contained in the subsartorial canal (*adductor canal*), on the roof of which the Sartorius lies (fig. 642).

Nerve-supply.—The Sartorius is supplied by the femoral nerve (L. 2 and 3).

Actions.—The Sartorius flexes the leg on the thigh, and the thigh on the pelvis; it also abducts the thigh and rotates it laterally. Acting from below it flexes the pelvis on the thigh and rotates it towards the opposite side.

The **Quadriceps femoris** (figs. 638, 640, 642) is the great extensor muscle of the leg, and consists of a large fleshy mass which covers the front and sides of the femur. It is subdivided into separate portions, which have received distinctive names. One occupies the middle of the thigh, and arises from the ilium; from its straight course it is called the *Rectus femoris*. The other three take origin from the body of the femur, which they cover from the trochanters to the condyles; that on the lateral side of the femur is termed the *Vastus lateralis*; that on the medial side, the *Vastus medialis*; and that in front, the *Vastus intermedius*.

The **Rectus femoris** (figs. 638, 640, 642) is fusiform in shape, and its superficial fibres are arranged in a bipennate manner, the deep fibres running straight down to the deep aponeurosis. It arises by two tendinous heads: a straight head from the anterior inferior iliac spine, and a reflected head, from a groove above the brim of the acetabulum. The two unite at an acute angle, and spread into an aponeurosis which is prolonged downwards on the anterior surface of the muscle, and from this the muscular fibres arise. The muscle ends in a broad and thick aponeurosis which occupies the lower two-thirds of its posterior surface, and, gradually becoming narrowed into a flattened tendon, is inserted into the base of the patella.

The **Vastus lateralis** (figs. 638, 640, 642) is the largest part of the Quadriceps femoris. It arises by a broad aponeurosis, which is attached to the upper part of the trochanteric line, to the anterior and inferior borders of the greater trochanter, to the lateral lip of the gluteal tuberosity, and to the upper one-half of the lateral lip of the linea aspera: this aponeurosis covers the upper three-fourths of the muscle, and from its deep surface many fibres take origin. A few additional fibres arise from the tendon of the Gluteus maximus, and from the lateral intermuscular septum between the Vastus lateralis and short head of the Biceps femoris. The fibres form a large fleshy mass which is attached to a strong aponeurosis placed on the deep surface of the lower part of the muscle: this aponeurosis contracts into a flat tendon which is inserted into the lateral border of the patella, blending with the Quadriceps femoris tendon. It gives to the capsule of the knee-joint an expansion which extends downwards to be attached to the lateral condyle of the tibia and blends with the iliotibial tract.

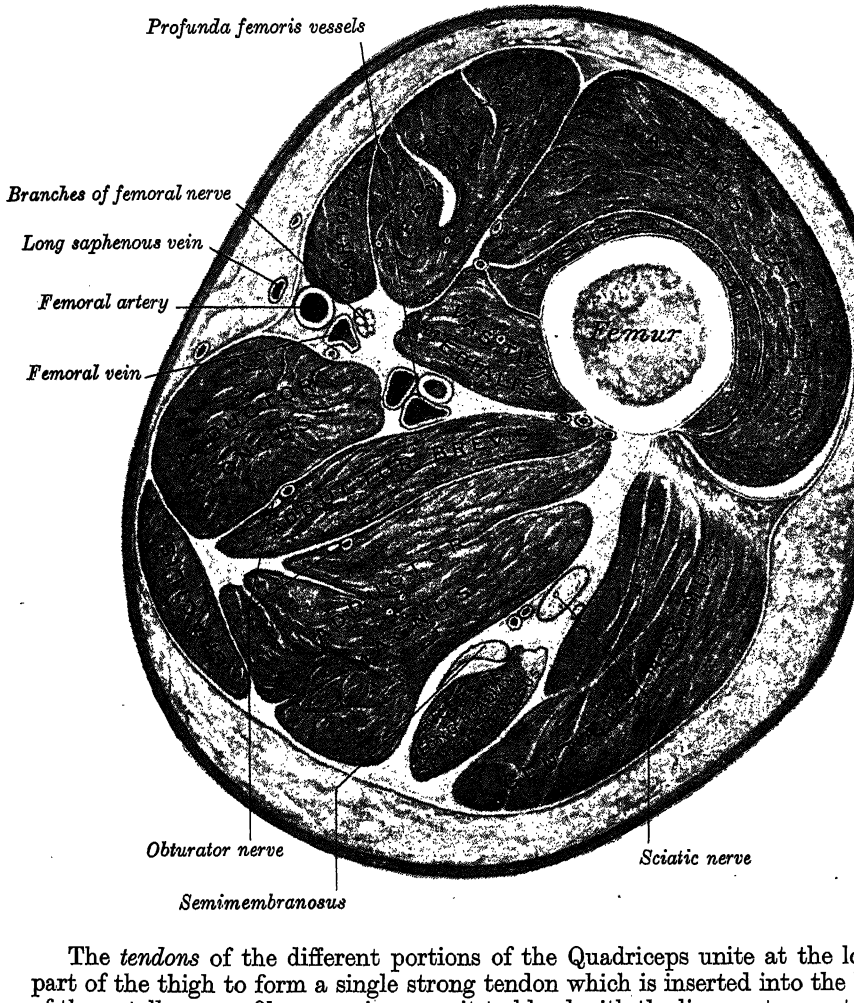
The Vastus medialis and Vastus intermedius appear to be inseparably united, but when the Rectus femoris has been reflected a narrow interval will be observed extending upwards from the medial border of the patella between the two muscles, and the separation may be carried to the lower part of the trochanteric line, where, however, the two muscles are frequently continuous.

The **Vastus medialis** (figs. 638, 640, 642) arises from the lower part of the trochanteric line, the spiral line, the medial lip of the linea aspera, the upper part of the medial supracondylar line, the tendons of the Adductor longus and Adductor magnus, and the medial intermuscular septum. Its fibres are directed downwards and forwards, and are chiefly attached to an aponeurosis which lies on the deep surface of the muscle and is inserted into the medial border of the

patella and the Quadriceps femoris tendon. An expansion from this tendon reinforces the capsule of the knee-joint and is attached below to the medial condyle of the tibia.

The **Vastus intermedius** (figs. 640, 642) arises from the front and lateral surfaces of the upper two-thirds of the shaft of the femur, and from the lower part of the lateral intermuscular septum. Its fibres end in a superficial aponeurosis which forms the deep part of the Quadriceps femoris tendon and, in addition, gains attachment to the lateral border of the patella and the lateral condyle of the tibia.

FIG. 640.—A transverse section through the thigh at the level of the apex of the femoral triangle. Four-fifths of natural size.



The *tendons* of the different portions of the Quadriceps unite at the lower part of the thigh to form a single strong tendon which is inserted into the base of the patella, some fibres passing over it to blend with the ligamentum patellæ. The patella may be regarded as a sesamoid bone developed in the tendon of the Quadriceps; and the ligamentum patellæ, which is continued from the apex of the patella to the tubercle of the tibia, may be regarded as the proper tendon of insertion of the muscle, the medial and lateral patellar retinacula (p. 493) being expansions from its borders. The suprapatellar bursa, which usually communicates with the cavity of the knee-joint, is situated between the femur and the portion of the Quadriceps tendon above the patella; the deep infrapatellar bursa is interposed between the ligamentum patellæ and the upper part of the front of the tibia (fig. 560).

The **Articularis genus** is a small muscle, usually distinct from the Vastus intermedius, but occasionally blended with it; it consists of several muscular

bundles which arise from the anterior surface of the lower part of the shaft of the femur and are inserted into the upper part of the synovial membrane of the knee-joint.

Nerve-supply.—The Quadriceps femoris and the Articularis genus are supplied by the femoral nerve (L. *2*, 3 and 4).

Actions.—The Quadriceps femoris extends the leg upon the thigh. The Rectus femoris assists the Psoas major and Iliacus in supporting the pelvis and trunk upon the femur; it also assists in flexing the thigh on the pelvis, or, if the thigh be fixed, it helps to flex the pelvis. The Vastus medialis draws the patella medially as well as upwards. The Articularis genus pulls the synovial membrane of the knee-joint upwards during extension of the leg.

2. The Medial Femoral Muscles

Gracilis.	Adductor longus.	Adductor magnus.
Pectineus.	Adductor brevis.	

The **Gracilis** (figs. 638, 640, 642) is the most superficial muscle on the medial side of the thigh. It is thin and flattened, broad above, narrow and tapering below. It arises by a thin aponeurosis from the medial margins of the lower one-half of the body of the pubis and the upper one-half of the inferior ramus. The fibres run vertically downwards, and end in a rounded tendon which passes across the medial condyle of the femur posterior to the tendon of Sartorius. It then curves round the medial condyle of the tibia, where it becomes flattened, and is inserted into the upper part of the medial surface of the shaft of the tibia, below the condyle. A few fibres from the lower part of the tendon are prolonged into the deep fascia of the leg. At its insertion the tendon is situated immediately above that of the Semitendinosus, and its upper edge is overlapped by the tendon of the Sartorius, with which it is in part blended. It is separated from the medial (tibial collateral) ligament of the knee-joint by the tibial intertendinous bursa (p. 499).

Nerve-supply.—The Gracilis is supplied by the obturator nerve (L. *2*, 3 and 4).

Actions.—The Gracilis flexes the leg and rotates it medially; it may also act as an adductor of the thigh, when necessary.

The **Pectineus** (fig. 638) is a flat, quadrangular muscle, situated at the front of the upper and medial part of the thigh. It arises from the pectineal line of the pubis, and to a slight extent from the surface of bone in front of it, between the iliopubic eminence (iliopectineal eminence) and pubic tubercle, and from the fascia covering the anterior surface of the muscle; the fibres pass downwards, backwards and laterally, to be inserted into the femur along a line leading from the lesser trochanter to the linea aspera.*

Relations.—Its *anterior surface* is in relation with the fascia lata, which separates it from the femoral vessels and long saphenous vein; its *posterior surface*, with the capsule of the hip-joint, the Adductor brevis, Obturator externus and the anterior branch of the obturator nerve; its *lateral border*, with the Psoas major and the medial circumflex femoral vessels; its *medial border*, with the upper or lateral margin of the Adductor longus.

Nerve-supply.—The Pectineus is supplied by the femoral nerve (L. 2 and 3); and by the accessory obturator (L. 3), when this nerve is present. Occasionally it receives a branch from the obturator nerve.

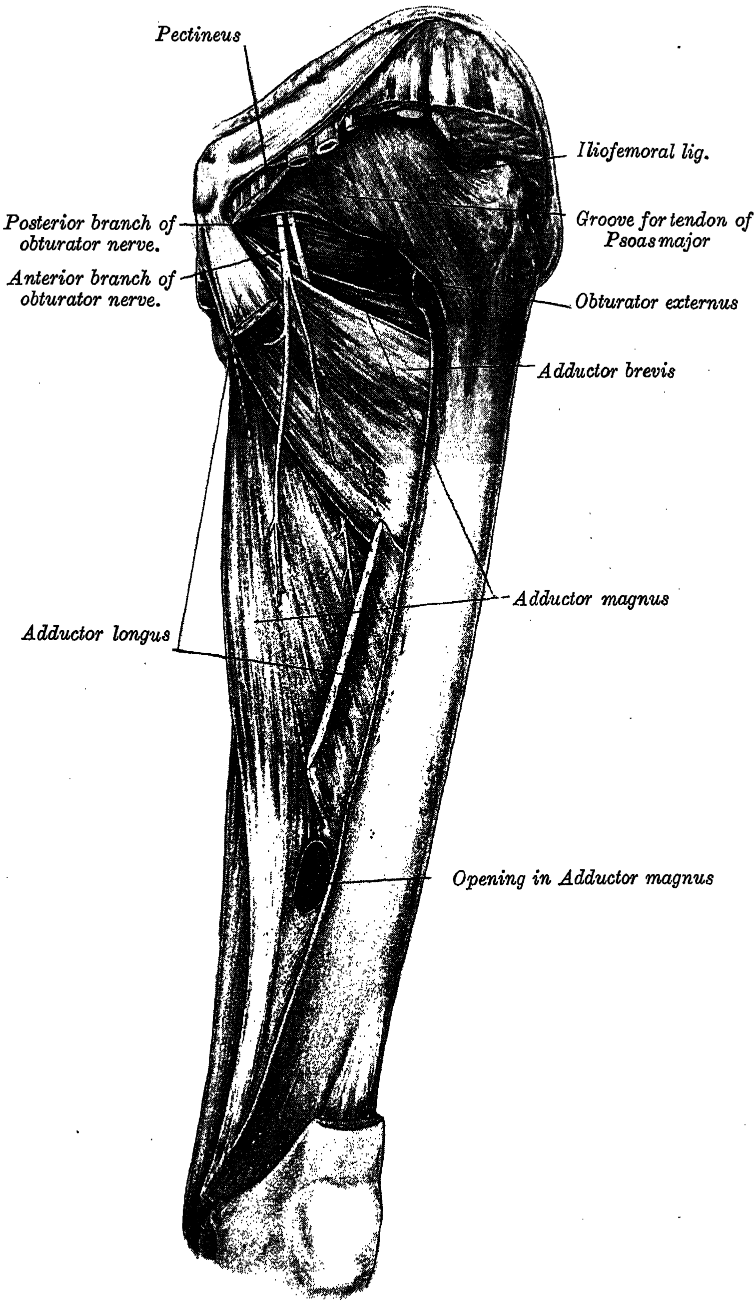
Actions.—The Pectineus adducts the thigh and flexes it on the pelvis.

The **Adductor longus** (figs. 641, 642), the most superficial of the three adductors, is a triangular muscle, lying in the same plane as the Pectineus. It arises by a flat, narrow tendon which is attached to the front of the pubis in the angle between the crest and the symphysis. It soon expands into a broad fleshy belly which passes downwards, backwards, and laterally, and is inserted, by an

* The Pectineus may consist of two incompletely separated strata: the lateral or dorsal stratum, which is constant, is supplied by a branch from the femoral nerve, or in the absence of this branch by the accessory obturator nerve; the medial or ventral stratum, when present, is a derivative of the adductor group of muscles and is supplied by the obturator nerve.—A. M. Paterson, *Journal of Anatomy and Physiology*, vol. xxvi. p. 43.

aponeurosis, into the middle one-third of the linea aspera of the femur, between the Vastus medialis and the Adductor magnus, with both of which it is usually blended.

Fig. 641.—The adductor muscles of the left thigh.



A portion of the Adductor longus has been excised, and the two heads of the Rectus femoris, which are not labelled, have been divided above the point where they unite.

Relations.—Its *anterior surface* is in relation with the spermatic cord, the fascia lata, by which it is separated from the long saphenous vein, and, near its insertion, with the femoral artery and vein and the Sartorius: its *posterior surface*, with the Adductores brevis et magnus, the anterior branch of the obturator nerve, and near its insertion with the

profunda femoris vessels; its *lateral border*, with the Pectineus; its *medial border*, with the Gracilis.

Nerve-supply.—The Adductor longus is supplied by the anterior division of the obturator nerve (L. 2 and 3).

Actions.—The Adductor longus adducts the thigh, flexes it on the pelvis, and rotates it laterally.

Applied Anatomy.—The Adductor longus is liable to be severely strained in those who ride much on horseback, or it may be ruptured by suddenly gripping the saddle. Occasionally, especially in cavalry soldiers, the tendon of origin becomes ossified, constituting the 'rider's bone.'

The **Adductor brevis** (figs. 640, 641) is situated behind the Pectineus and Adductor longus. It is somewhat triangular in form, and arises by a narrow origin from the outer surface of the inferior ramus of the pubis, between the Gracilis and Obturator externus. Its fibres, passing backwards, laterally, and downwards, are inserted by an aponeurosis into the femur, along the line leading from the lesser trochanter to the linea aspera, and into the upper part of the linea aspera immediately behind the Pectineus and the upper part of the Adductor longus.

Relations.—Its *anterior surface* is in relation with the Pectineus, Adductor longus, arteria profunda femoris, and anterior branch of the obturator nerve; its *posterior surface*, with the Adductor magnus, and posterior branch of the obturator nerve; its *upper border*, with the medial circumflex femoral artery, the Obturator externus, and conjoined tendon of the Psoas major and Iliacus; its *lower* or *medial border*, with the Gracilis and Adductor magnus. It is pierced near its insertion by the second, or first and second, perforating arteries.

Nerve-supply.—The Adductor brevis is supplied by the obturator nerve (L. 2, 3 and *4*).

Actions.—The Adductor brevis adducts the thigh, flexes it on the pelvis and rotates it laterally.

The **Adductor magnus** (figs. 640, 641, 642) is a large triangular muscle, situated on the medial side of the thigh. It arises from a small part of the inferior ramus of the pubis, from the ramus of the ischium, and from the lateral portion of the inferior part of the tuberosity of the ischium. Those fibres which arise from the ramus of the pubis are short, horizontal in direction, and are inserted into the medial margin of the gluteal tuberosity of the femur, medial to the Gluteus maximus *; those from the ramus of the ischium are directed downwards and laterally with different degrees of obliquity, to be inserted, by means of a broad aponeurosis, into the linea aspera and the upper part of the medial supracondylar line. The medial portion of the muscle, composed principally of the fibres arising from the tuberosity of the ischium, forms a thick fleshy mass which descends almost vertically, and ends about the lower one-third of the thigh in a rounded tendon. This tendon is inserted into the adductor tubercle on the medial condyle of the femur, and is connected by a fibrous expansion to the medial supracondylar line. At the insertion of the muscle, there is a series of osseo-aponeurotic openings, formed by tendinous arches attached to the bone. The upper four openings are small, and give passage to the perforating branches of the arteria profunda femoris. The lowest is of large size, and transmits the femoral vessels to the popliteal fossa.

Relations.—Its *anterior surface* is in relation with the Pectineus, Adductores brevis et longus, the femoral and profunda vessels, and the posterior branch of the obturator nerve; a bursa intervenes between the highest part of the muscle and the lesser trochanter of the femur; its *posterior surface*, with the sciatic nerve, the Gluteus maximus, Biceps femoris, Semitendinosus and Semimembranosus. Its *superior border* lies parallel with the Quadratus femoris, the transverse branch of the medial circumflex femoral artery passing between them; its *medial border* is in relation with the Gracilis, Sartorius and fascia lata.

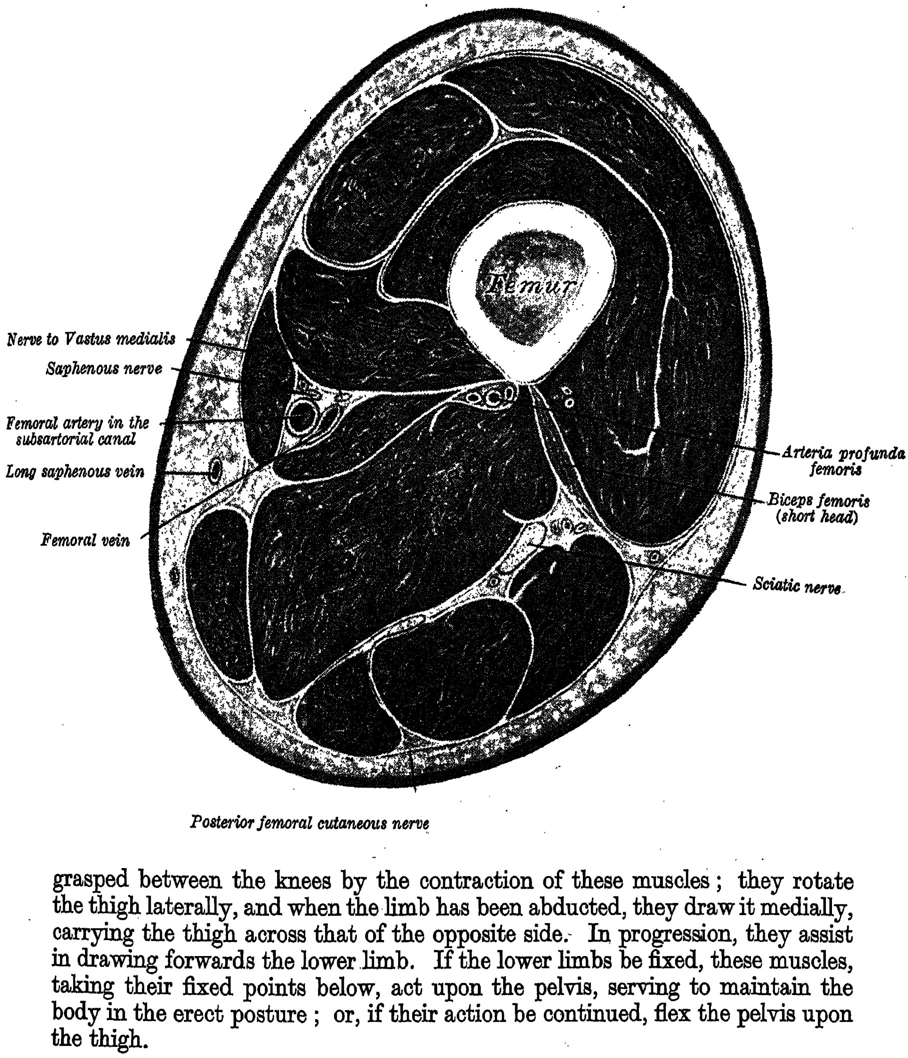
Nerve-supply.—The Adductor magnus is a composite muscle and derives its nerve-supply from two sources. The true adductor part of the muscle is

* These uppermost fibres are sometimes described as a separate muscle—the *Adductor minimus*—which is situated somewhat in front of the other parts of the muscle.

supplied by the obturator nerve (L. 3 and 4); the part which takes origin from the tuberosity of the ischium is a derivative of the hamstring muscles and is supplied by the sciatic nerve (L. 4 and 5).

Actions.—The Adductor magnus adducts the thigh and rotates it laterally; the pubic fibres flex the thigh on the pelvis, but the ischial fibres have the opposite action. The Pectineus and the Adductores adduct the thigh powerfully; they are especially used in horse exercise, the sides of the saddle being

FIG. 642.—A transverse section through the middle of the thigh. Four-fifths of natural size.



grasped between the knees by the contraction of these muscles; they rotate the thigh laterally, and when the limb has been abducted, they draw it medially, carrying the thigh across that of the opposite side. In progression, they assist in drawing forwards the lower limb. If the lower limbs be fixed, these muscles, taking their fixed points below, act upon the pelvis, serving to maintain the body in the erect posture; or, if their action be continued, flex the pelvis upon the thigh.

3. The Muscles of the Gluteal Region (figs. 643, 644)

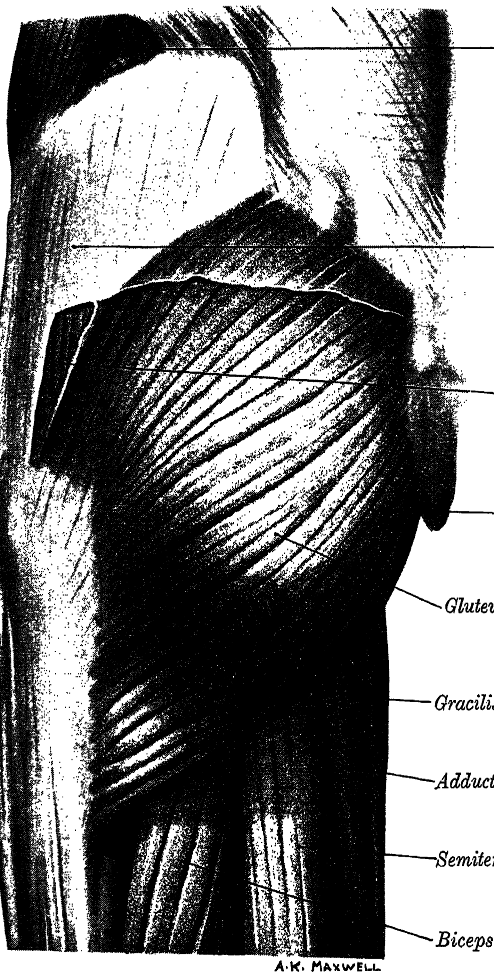
Gluteus maximus.	Obturator internus.
Gluteus medius.	Gemellus superior.
Gluteus minimus.	Gemellus inferior.
Piriformis.	Quadratus femoris.

Obturator externus.

The **Gluteus maximus** (fig. 643) is the largest and most superficial muscle in the gluteal region. It is a broad and thick fleshy mass of a quadrilateral shape,

and forms the prominence of the buttock. Its large size is one of the most characteristic features of the muscular system in man, connected as it is with the power he has of maintaining the trunk in the erect position. The muscle is remarkably coarse in structure, being made up of fasciculi lying parallel with one another, and collected into large bundles separated by fibrous septa. It arises from the posterior gluteal line of the ilium, and the rough portion of bone, including the crest, immediately above and behind it; from the aponeurosis of the Sacrospinalis; from the posterior surface of the lower part of the sacrum and the side of the coccyx; from the sacrotuberous ligament, and from the

FIG. 643.—The left Gluteus maximus muscle.



A portion of the strong gluteal fascia has been removed to expose the Gluteus medius.

fascia (gluteal aponeurosis) covering the Gluteus medius. The fibres run obliquely downwards and laterally; those forming the upper and larger portion of the muscle, together with the superficial fibres of the lower portion, end in a thick tendinous lamina which passes across the greater trochanter, and is inserted into the iliotibial tract of the fascia lata; the deeper fibres of the lower portion of the muscle are inserted into the gluteal tuberosity of the femur between the Vastus lateralis and Adductor magnus.

Three *bursæ* are usually found in relation with the deep surface of this muscle. One, of large size (*trochanteric bursa of Gluteus maximus*), and generally multilocular, separates it from the greater trochanter; a second is found between

the tendon of the muscle and that of the Vastus lateralis (*gluteofemoral bursa*); a third, often wanting (*ischial bursa of Gluteus maximus*), is situated on the tuberosity of the ischium.

Relations.—Its *superficial surface* is in relation with a thin fascia which separates it from the subcutaneous tissue; its *deep surface*, with the ilium, sacrum, coccyx, and sacrotuberous ligament, part of the Gluteus medius, Piriformis, Gemelli, Obturator internus, Quadratus femoris, the tuberosity of the ischium, greater trochanter, the origins of the Biceps femoris, Semitendinosus, Semimembranosus and the Adductor magnus. The superficial part of the superior gluteal artery reaches the deep surface of the muscle by passing between the Piriformis and the Gluteus medius; the inferior gluteal and internal pudendal vessels and the sciatic, pudendal, and posterior femoral cutaneous nerves and muscular branches from the sacral plexus, issue from the pelvis below the Piriformis. The first perforating artery and the terminal branches of the medial circumflex femoral artery are also found under cover of the lower part of the muscle. Its *upper border* is thin, and overlies the Gluteus medius. Its *lower border* is free and prominent, and is crossed by the fold of the nates.

Nerve-supply.—The Gluteus maximus is supplied by the inferior gluteal nerve (L. 5 and S. 1 and 2).

Actions.—When the Gluteus maximus takes its fixed point from the pelvis, it extends the thigh and brings it into line with the trunk. Taking its fixed point below, it supports the pelvis and the trunk upon the head of the femur. Its most powerful action is to raise the trunk after stooping by drawing the pelvis backwards. It is a tensor of the fascia lata, and through the iliotibial tract it steadies the femur on the tibia during standing, when the extensor muscles are relaxed.

The **Gluteus medius** is a broad, thick muscle which is situated on the outer surface of the pelvis. Its posterior one-third is covered by the Gluteus maximus; its anterior two-thirds is superficial and is covered only by a strong layer of deep fascia (fig. 643). It arises from the outer surface of the ilium between the iliac crest and posterior gluteal line above, and the middle gluteal line below; it also arises from the strong fascia which covers the upper part of its outer surface. The fibres converge to a flattened tendon which is inserted into the oblique ridge directed downwards and forwards on the lateral surface of the greater trochanter of the femur. A bursa (*trochanteric bursa of Gluteus medius*) separates the tendon from the anterosuperior part of the lateral surface of the trochanter, over which it glides.

The **Gluteus minimus** (fig. 644), the smallest of the Glutei, is placed immediately under cover of the preceding. It is fan-shaped, arising from the outer surface of the ilium between the middle and inferior gluteal lines, and, behind, from the margin of the greater sciatic notch. The fibres converge to the deep surface of an aponeurosis, and this ends in a tendon which is inserted into a ridge on the lateral part of the anterior surface of the greater trochanter of the femur, and gives an expansion to the capsule of the hip-joint. A bursa (*trochanteric bursa of Gluteus minimus*) is interposed between the tendon and the medial part of the anterior surface of the greater trochanter.

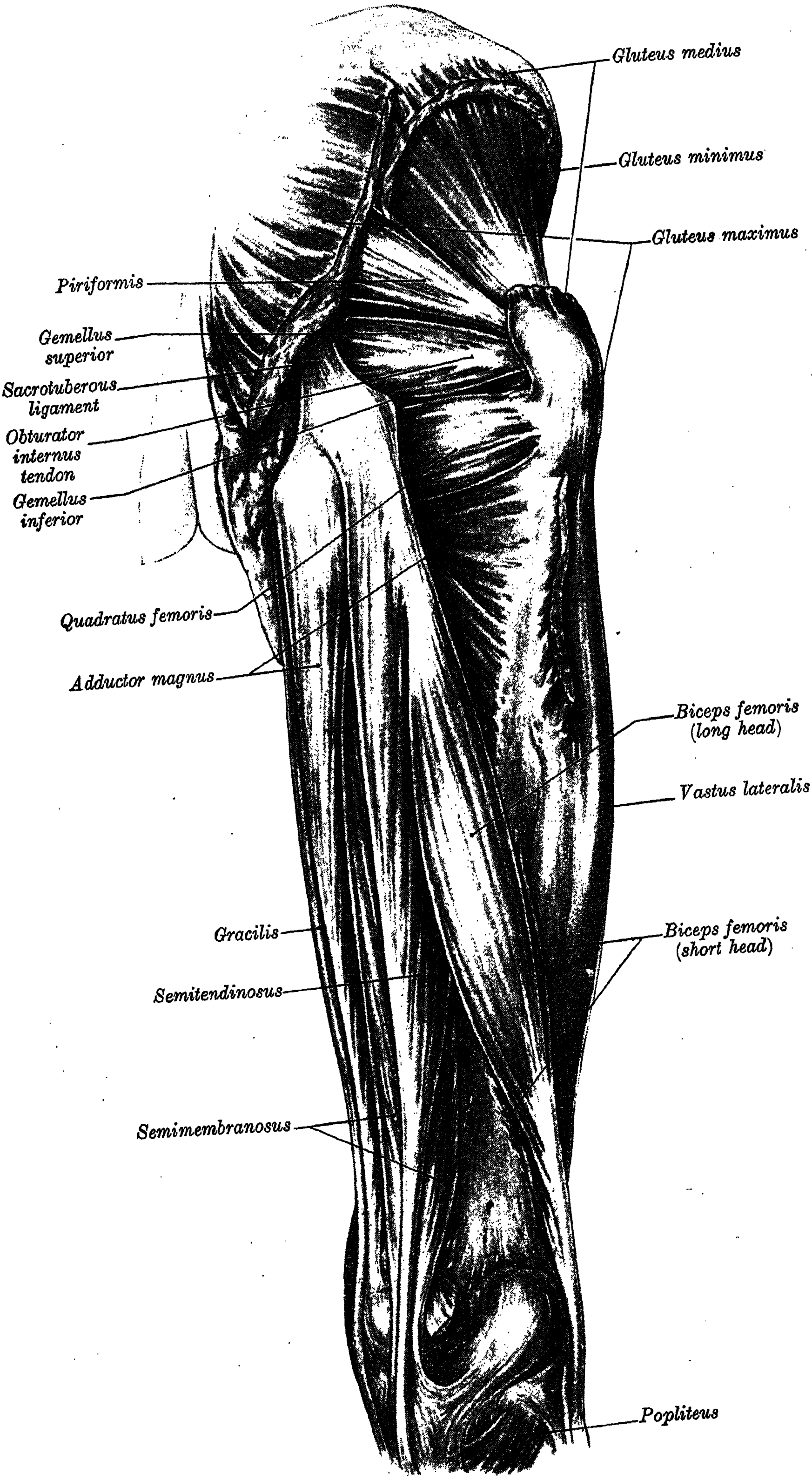
Between the Gluteus medius and Gluteus minimus are the deep branches of the superior gluteal vessels, and the superior gluteal nerve. The reflected tendon of the Rectus femoris and the capsule of the hip-joint are placed deep to the Gluteus minimus.

Nerve-supply.—Both the Gluteus medius and the Gluteus minimus are supplied by the superior gluteal nerve (L. 4 and 5 and S. 1).

Actions.—Both the preceding muscles, acting from the pelvis, abduct the thigh and rotate it medially. Acting from the femur, they produce the slight rotation of the pelvis which occurs in walking and running, and keep the transverse axis of the pelvis horizontal, or nearly horizontal, while the opposite limb is unsupported, e.g. when the foot is off the ground in walking or running.

The **Piriformis** (fig. 644) lies almost parallel with the posterior margin of the Gluteus medius. It is situated partly within the pelvis on its posterior wall, and partly at the back of the hip-joint. It arises from the front of the sacrum by three fleshy digitations, attached to the portions of bone between the anterior sacral foramina, and to the grooves leading from the foramina (fig. 276): a few

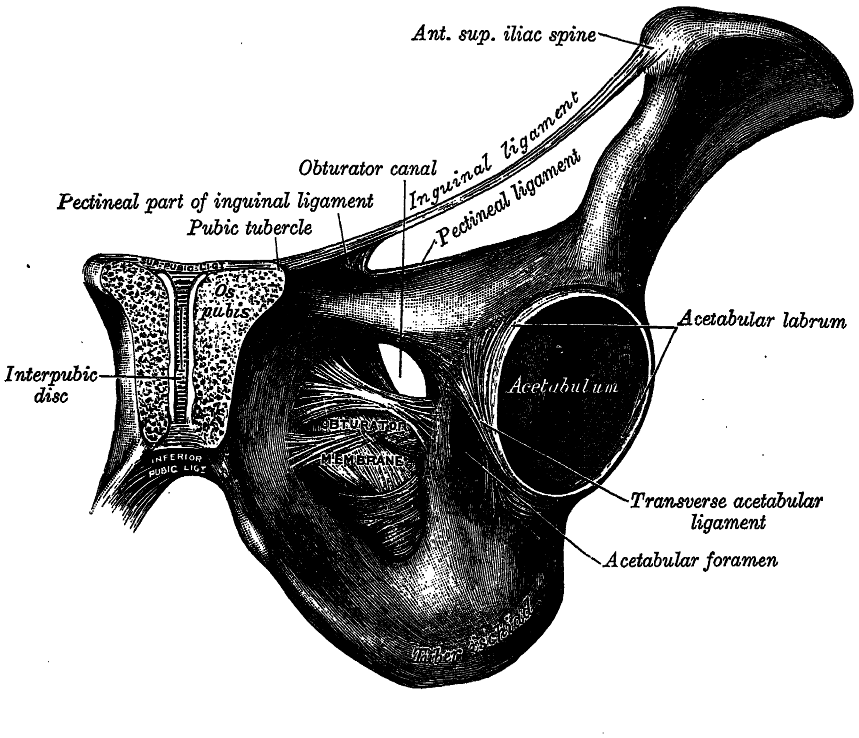
Fig. 644.—The muscles of the gluteal region and the posterior muscles of the thigh. Right side.



fibres also arise from the margin of the greater sciatic foramen, and from the upper part of the anterior surface of the sacrotuberous ligament. The muscle passes out of the pelvis through the greater sciatic foramen, and is inserted by a rounded tendon into the upper border of the greater trochanter of the femur, behind and above, but often partly blended with, the common tendon of the Obturator internus and Gemelli.

Relations.—*Within the pelvis* the *anterior surface* of the Piriformis is in relation with the rectum (especially on the left side), the sacral plexus of nerves and branches of the internal iliac vessels; its *posterior surface*, with the sacrum. *Outside the pelvis*, its *anterior surface* is in contact with the posterior surface of the ischium and capsule of the hip-joint; and its *posterior surface*, with the Gluteus maximus. Its *upper border* is in relation with the Gluteus medius, and the superior gluteal vessels and nerve; its *lower border*, with the Coccygeus and Gemellus superior. The inferior gluteal and internal pudendal vessels, and

Fig. 645.—The left Obturator membrane. External surface.



the sciatic, posterior femoral cutaneous and pudendal nerves, and muscular branches from the sacral plexus, appear in the buttock between the Piriformis and Gemellus superior. The muscle is frequently pierced by the lateral popliteal (common peroneal nerve).

Nerve-supply.—The Piriformis is supplied by twigs from the first and second sacral nerves.

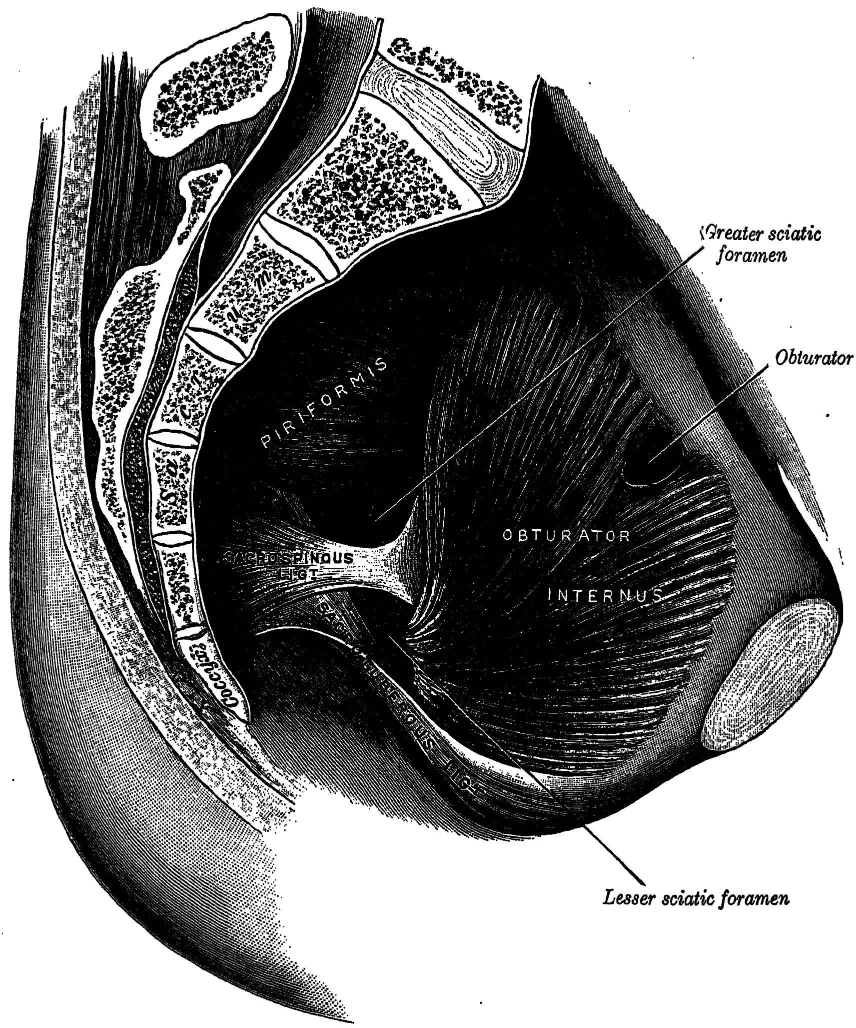
Actions.—The Piriformis rotates the thigh laterally.

The **obturator membrane** (fig. 645) is a thin, fibrous sheet which nearly closes the obturator foramen. Its fibres are arranged in interlacing bundles mainly transverse in direction; the uppermost bundle is attached to the obturator tubercles and completes the obturator canal for the passage of the obturator vessels and nerve. The membrane is attached to the sharp margin of the obturator foramen except at its lower lateral angle, where it is fixed to the pelvic surface of the ramus of the ischium, i.e. within the margin of the foramen. Both Obturator muscles take origin from this membrane, and some of the fibres of the pubofemoral ligament of the hip-joint are attached to its inferior surface.

The **Obturator internus** (fig. 646) is situated partly within the true pelvis,

and partly at the back of the hip-joint. It arises from the inner surface of the anterolateral wall of the pelvis, where it surrounds the greater part of the obturator foramen, being attached to the inferior ramus of the pubis, the ramus of the ischium and to the inner surface of the hip-bone below and behind the pelvic brim, reaching from the upper part of the greater sciatic foramen above and behind, to the obturator foramen below and in front (fig. 440). It also arises from the medial part of the pelvic surface of the obturator membrane,

FIG. 646.—The left Obturator internus. Pelvic surface.



from the tendinous arch which completes the canal for the passage of the obturator vessels and nerve, and to a slight extent from the obturator fascia, which covers the muscle. The fibres converge rapidly towards the lesser sciatic foramen and end in four or five tendinous bands in the deep surface of the muscle; these bands make a right-angled bend over the grooved surface of the ischium between its spine and tuberosity. The grooved surface is covered by smooth cartilage, which is separated from the tendon by a bursa, and presents one or more ridges corresponding with the furrows between the tendinous bands. These bands leave the pelvis through the lesser sciatic foramen and unite into a single flattened tendon, which passes horizontally across the capsule of the hip-joint, and, after receiving the attachments of the Gemelli, is inserted into the fore part of the medial surface of the greater trochanter of the femur,

above and in front of the trochanteric fossa. A bursa, narrow and elongated in form, is usually found between the tendon and the capsule of the hip-joint; it occasionally communicates with the bursa between the tendon and the ischium.

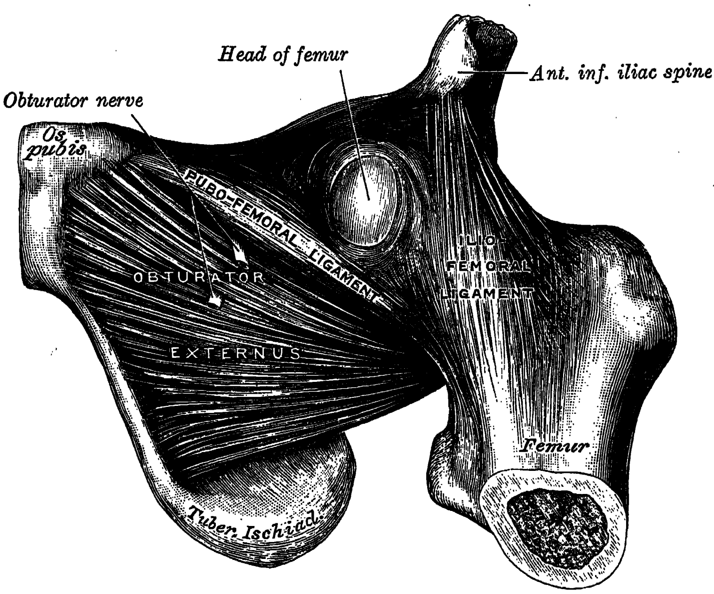
Relations.—*Within the pelvis,* the *anterolateral surface* of the muscle is in relation with the obturator membrane and inner surface of the lateral wall of the pelvis; its *pelvic surface,* with the obturator fascia, and the origin of the Levator ani, and with the internal pudendal vessels and pudendal nerve, which cross it. The pelvic surface forms the lateral boundary of the ischiorectal fossa. *Outside the pelvis,* the muscle is covered by the Gluteus maximus, is crossed by the sciatic nerve, and rests on the back of the hip-joint. As the tendon of the Obturator internus emerges from the lesser sciatic foramen it is overlapped both in front and behind by the two Gemelli, which form a muscular canal for it; near its insertion the Gemelli pass in front of the tendon and form a groove in which it lies.

Nerve-supply.—The nerve to Obturator internus derives its fibres from L. 5 and S. 1 and 2.

The **Gemelli** (fig. 644) are two small muscular fasciculi, accessories to the tendon of the Obturator internus.

The **Gemellus superior,** the smaller of the two, arises from the outer surface

FIG. 647.—The left Obturator externus.



of the spine of the ischium, blends with the upper part of the tendon of the Obturator internus, and is inserted with it into the medial surface of the greater trochanter of the femur. It is sometimes wanting.

Nerve-supply.—The Gemellus superior is supplied by the nerve to the Obturator internus (L. 5 and S. 1 and 2).

The **Gemellus inferior** arises from the upper part of the tuberosity of the ischium, immediately below the groove for the Obturator internus tendon. It blends with the lower part of the tendon of the Obturator internus, and is inserted with it into the medial surface of the greater trochanter.

Nerve-supply.—The Gemellus inferior is supplied by the nerve to the Quadratus femoris (L. 4 and 5 and S. 1).

Actions.—The Obturator internus and the Gemelli rotate the thigh laterally.

The **Quadratus femoris** (fig. 644) is a flat, quadrilateral muscle, between the Gemellus inferior and the upper margin of the Adductor magnus; it is separated from the latter by the transverse branch of the medial circumflex femoral artery. It arises from the upper part of the external border of the tuberosity of the ischium, and is inserted into a small tubercle on the upper part of the trochanteric crest of the femur, and for a short distance into the bone below. As it passes to its insertion the muscle lies posterior to the articular capsule

of the hip-joint and the neck of the femur, but it is separated from them by the tendon of the Obturator externus and the ascending branch of the medial circumflex femoral artery. A bursa is often found between the front of this muscle and the lesser trochanter.

Nerve-supply.—The nerve to Quadratus femoris derives its fibres from L. 4 and 5 and S. 1.

Action.—The Quadratus femoris is a lateral rotator of the thigh.

The **Obturator externus** (fig. 647) is a flat, triangular muscle which covers the outer surface of the anterior wall of the pelvis. It arises from the margin of bone immediately around the medial side of the obturator foramen, viz. from the rami of the pubis, and the ramus of the ischium; it also arises from the medial two-thirds of the outer surface of the obturator membrane, and from the tendinous arch which completes the canal for the passage of the obturator vessels and nerves. The fibres springing from the ramus of the ischium extend for a short distance on to the pelvic surface of the bone, where they obtain a narrow origin between the margin of the foramen and the attachment of the obturator membrane (p. 635). The fibres converge and pass backwards, laterally and upwards, and end in a tendon which runs across the back of the neck of the femur and lower part of the capsule of the hip-joint and is inserted into the trochanteric fossa of the femur. The obturator vessels lie between the muscle and the obturator membrane; the anterior branch of the obturator nerve reaches the thigh by passing in front of the muscle, and the posterior branch by piercing it.

Nerve-supply.—The Obturator externus is supplied by the posterior branch of the obturator nerve (L. 3 and 4).

Action.—The Obturator externus is a lateral rotator of the thigh.

4. The Posterior Femoral Muscles (fig. 644)

Biceps femoris. Semitendinosus. Semimembranosus.

The **Biceps femoris** (figs. 640, 642, 644) is situated on the posterolateral surface of the thigh. It has two heads of origin: one, the long head, arises from the lower and medial impression on the upper part of the ischial tuberosity (fig. 442) by a tendon common to it and the Semitendinosus, and from the lower part of the sacrotuberous ligament; the other, the short head, from the lateral lip of the linea aspera of the femur, between the Adductor magnus and Vastus lateralis, extending up almost as high as the insertion of the Gluteus maximus; from the lateral supracondylar line to within 5 cm. of the lateral condyle; and from the lateral intermuscular septum. The fibres of the long head form a fusiform belly which passes downwards and laterally across the sciatic nerve to end in an aponeurosis; this aponeurosis covers the posterior surface of the muscle, receives on its deep surface the fibres of the short head, and gradually contracts into a tendon which is inserted into the lateral side of the head of the fibula, and by a small slip into the lateral condyle of the tibia. This tendon forms the lateral hamstring and divides into two portions, which embrace the lateral ligament of the knee-joint; from its posterior border a thin expansion is given off to the fascia of the leg. The lateral popliteal (common peroneal) nerve descends along the medial border of the tendon and separates it, below, from the lateral head of the gastrocnemius.

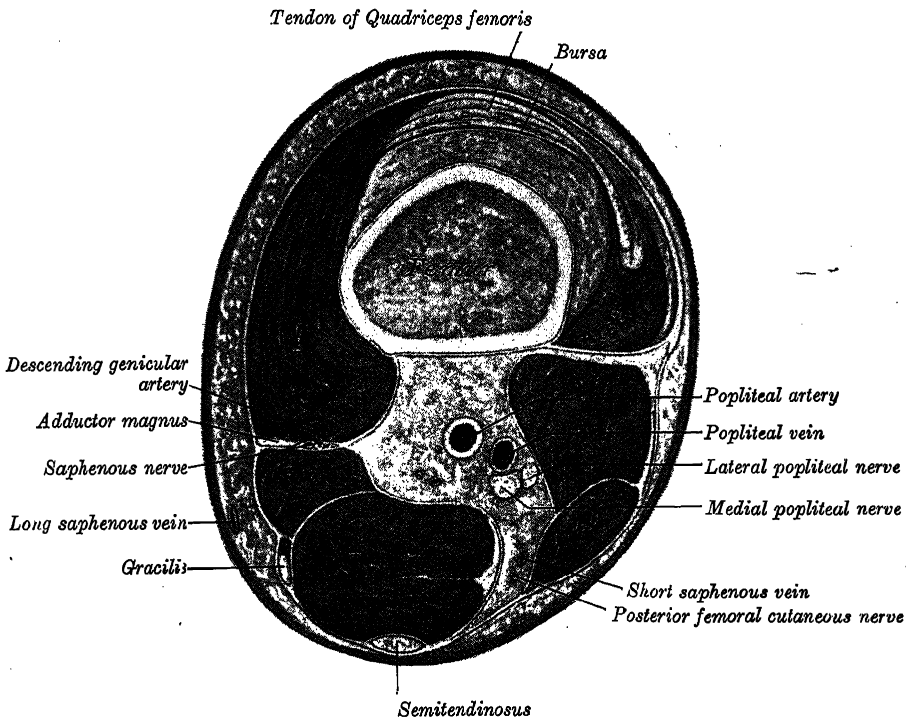
Nerve-supply.—The Biceps femoris is supplied by the sciatic nerve; the long head through the medial popliteal (tibial) nerve (L. 5 and S. 1), the short head through the lateral popliteal (common peroneal) nerve (S. 2 and S. 3).

Actions.—The Biceps femoris, acting from above, flexes the leg on the thigh, and when the knee is semiflexed rotates the leg slightly laterally. Acting from below, it serves to support the pelvis on the head of the femur and draws the trunk backwards as in raising it from the stooping position.

The **Semitendinosus** (figs. 642, 644), remarkable for the great length of its tendon of insertion, is situated at the posteromedial surface of the thigh. It arises from the lower and medial impression on the upper part of the tuberosity of the ischium, by a tendon common to it and the long head of the Biceps femoris;

it also arises from an aponeurosis connecting the adjacent surfaces of the two muscles to the extent of about 7·5 cm. from their origin. The muscle is fusiform and ends a little below the middle of the thigh in a long, round tendon which lies on the surface of the Semimembranosus muscle ; the tendon curves around the medial condyle of the tibia, passes over the medial ligament of the knee-joint, from which it is separated by a bursa, and is inserted into the upper part of the medial surface of the shaft of the tibia behind the insertion of the Sartorius and below that of the Gracilis. At its insertion it is united with the tendon of the Gracilis and gives off a prolongation to the deep fascia of the leg. A tendinous intersection is usually observed about the middle of the muscle.

FIG. 648.—A transverse section through the thigh, 4 cm. above the adductor tubercle of the femur. Four-fifths of natural size.



Nerve-supply.—The Semitendinosus is supplied by the sciatic nerve through the medial popliteal (tibial) portion (L. *4* and 5 and S. 1 and *2*).

Actions.—Acting from above, it flexes the knee-joint and, when the joint is semiflexed, rotates the leg slightly medially. When its fixed point is below, its action is similar to that of the Biceps femoris.

The **Semimembranosus** (figs. 642, 644, 648), so called from its membranous tendon of origin, is situated at the back and medial side of the thigh. It arises by a thick tendon from the upper and lateral impression on the tuberosity of the ischium (fig. 442), above and lateral to the Biceps femoris and Semitendinosus, and is inserted into the groove on the back of the medial condyle of the tibia. The tendon of origin expands into an aponeurosis which passes downwards under cover of the Semitendinosus and long head of the Biceps femoris ; from this aponeurosis muscular fibres arise, and converge to another aponeurosis which covers the lower part of the posterior surface of the muscle and contracts into the tendon of insertion. The tendon of insertion gives off certain fibrous expansions : one, of considerable size, passes upwards and laterally to be inserted into the intercondylar line and lateral condyle of the femur, forming the oblique posterior (oblique popliteal) ligament of the knee-joint ; a second is continued downwards to the fascia which covers the Popliteus muscle ; while a few fibres join the medial ligament of the knee-joint and the fascia of the leg. The

muscle overlaps the upper part of the popliteal vessels and is itself overlapped and partly hidden by the Semitendinosus muscle throughout its whole extent (fig. 644).

The tendons of insertion of the Semitendinosus and Semimembranosus form the medial hamstrings.

Nerve-supply.—The Semimembranosus is supplied by the sciatic nerve through the medial popliteal (tibial) portion (L. 4 and 5 and S. *1*).

Actions.—The actions of the Semimembranosus are similar to those of the Semitendinosus.

Applied Anatomy.—In disease of the knee-joint, contraction of the hamstring tendons is a frequent complication; this causes flexion of the leg, and a partial dislocation of the tibia backwards, with a slight degree of lateral rotation, probably due to the action of the Biceps femoris. The hamstring tendons occasionally require subcutaneous division. The relation of the lateral popliteal nerve, which lies in close apposition to the medial border of the tendon of the Biceps femoris, must always be borne in mind in dividing this tendon, and a free incision with exposure of the tendon, before division, is the safer proceeding.

III. The Muscles of the Leg

The muscles of the leg may be divided into three groups: anterior, posterior, and lateral.

1. The Anterior Crural Muscles (fig. 650)

Tibialis anterior.	Extensor digitorum longus.
Extensor hallucis longus.	Peroneus tertius.

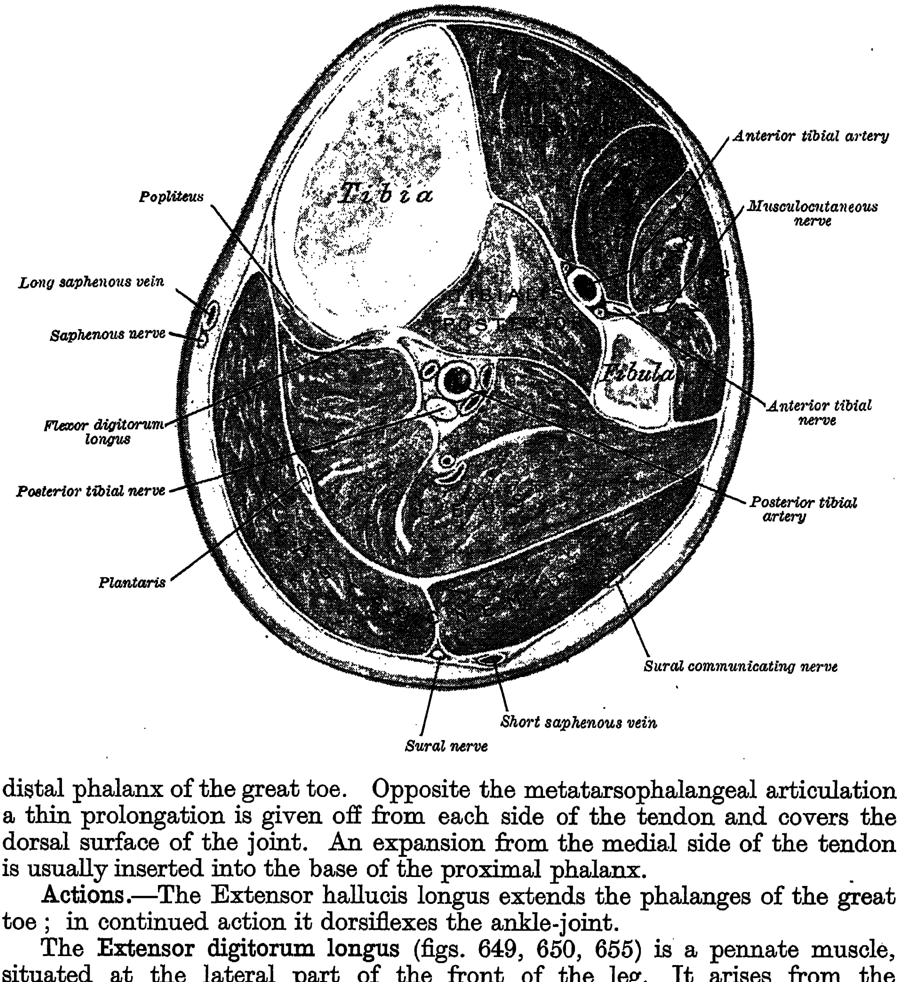
The **fascia cruris** or deep fascia of the leg is continuous above with the fascia lata, and is attached around the knee to the patella, the ligamentum patellæ, the tubercle and condyles of the tibia and the head of the fibula. Behind, it forms the popliteal fascia, which covers the popliteal fossa; here it is strengthened by transverse fibres, and perforated by the short saphenous vein. It receives an expansion from the tendon of the Biceps femoris laterally, and expansions from the tendons of the Sartorius, Gracilis, Semitendinosus and Semimembranosus medially; it blends with the periosteum covering the subcutaneous surface of the tibia, and with that covering the head and malleolus of the fibula; below, it is continuous with the extensor and flexor retinacula (transverse crural and laciniate ligaments). It is thick and dense in the upper and anterior part of the leg, and gives origin, by its deep surface, to some fibres of the Tibialis anterior and Extensor digitorum longus; it is thinner behind, where it covers the Gastrocnemius and Soleus. On the lateral side of the leg it gives off the *anterior* and *posterior crural intermuscular septa*, which are attached respectively to the anterior and posterior borders of the fibula; in the anterior and posterior crural regions the fascia also gives off several slender processes which enclose the individual muscles. A broad, transverse, intermuscular septum, called the *deep transverse fascia of the leg*, intervenes between the superficial and deep muscles on the back of the leg.

The **Tibialis anterior** (figs. 649, 650) is situated on the lateral side of the tibia; it is thick and fleshy above, tendinous below. It arises from the lateral condyle and upper one-half or two-thirds of the lateral surface of the shaft of the tibia; from the adjoining part of the anterior surface of the interosseous membrane; from the deep surface of the fascia cruris; and from the intermuscular septum between it and the Extensor digitorum longus. The fibres run vertically downwards, and end in a tendon which is apparent on the anterior surface of the muscle at the lower one-third of the leg; it passes through the medial compartments of the superior and inferior extensor retinacula (transverse and cruciate crural ligaments), inclines towards the medial side of the foot, and is inserted into the medial and under surfaces of the medial cuneiform bone, and the base of the first metatarsal bone. This muscle overlaps the anterior tibial vessels and nerve in the upper part of the leg.

Actions.—The Tibialis anterior is a dorsiflexor of the ankle-joint; it also raises the medial border of the foot, i.e. inverts the foot.

The **Extensor hallucis longus** (figs. 650, 655) lies between, and is partly hidden by, the Tibialis anterior and the Extensor digitorum longus. It arises from the anterior surface of the fibula for about the middle two-fourths of its extent, medial to the origin of the Extensor digitorum longus; it also arises from the anterior surface of the interosseous membrane to a similar extent. The anterior tibial vessels and nerve lie between it and the Tibialis anterior. The fibres pass downwards, and end in a tendon which occupies the anterior border of the muscle. It passes deep to the superior and through the inferior extensor retinaculum, crosses to the medial side of the anterior tibial vessels near the ankle-joint, and is inserted into the dorsal aspect of the base of the

FIG. 649.—A transverse section through the leg, 9 cm. below the knee-joint.



distal phalanx of the great toe. Opposite the metatarsophalangeal articulation a thin prolongation is given off from each side of the tendon and covers the dorsal surface of the joint. An expansion from the medial side of the tendon is usually inserted into the base of the proximal phalanx.

Actions.—The Extensor hallucis longus extends the phalanges of the great toe; in continued action it dorsiflexes the ankle-joint.

The **Extensor digitorum longus** (figs. 649, 650, 655) is a pennate muscle, situated at the lateral part of the front of the leg. It arises from the lateral condyle of the tibia, the upper three-fourths of the anterior surface of the shaft of the fibula, the upper part of the anterior surface of the interosseous membrane, the deep surface of the fascia cruris, the anterior crural intermuscular septum and the septum between it and the Tibialis anterior. In the upper part of the leg the anterior tibial vessels and nerve intervene between the muscle and the Tibialis anterior and, at a lower level, the Extensor hallucis longus also intervenes between them. The tendon of the Extensor digitorum longus passes behind the superior extensor retinaculum and within the loop of the inferior extensor retinaculum in company with the Peroneus tertius (fig. 656). It divides into four slips, which run forward on the dorsum of the foot, and are inserted into the middle and distal phalanges of the four lesser toes. Opposite the metatarsophalangeal

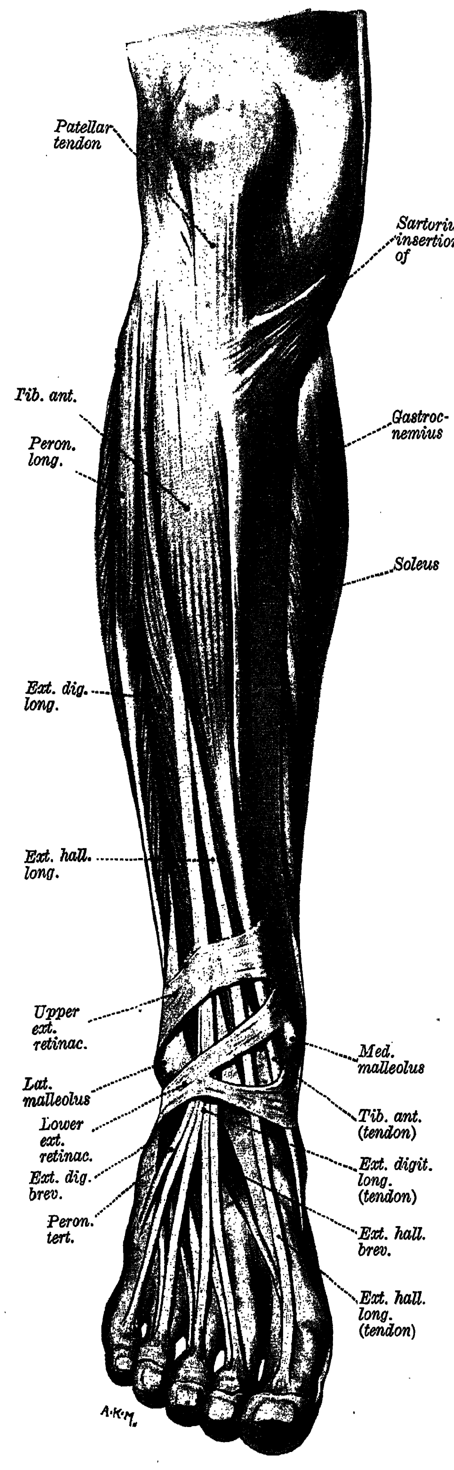


FIG. 650.—Muscles on extensor aspect of leg. (From Quain's *Anatomy*, XI. Edition.)

joints the tendons to the second, third, and fourth toes are each joined on the lateral side by a tendon of the Extensor digitorum brevis. The tendons are inserted as follows : each receives a fibrous expansion from the corresponding Lumbrical and Interosseous muscles, and then spreads out into a broad aponeurosis which covers the dorsal surface of the proximal phalanx ; at the joint of the proximal with the middle phalanx this aponeurosis divides into three slips—an intermediate, which is inserted into the base of the middle phalanx ; and two collateral slips, which, after uniting with each other on the dorsal surface of the middle phalanx, are inserted into the base of the distal phalanx.

Actions.—The Extensor digitorum longus extends the toes at the metatarsophalangeal joints, and when its action is continued dorsiflexes the ankle joint.

The Peroneus tertius (figs. 650, 657) is a part of the Extensor digitorum longus, and might be described as its fifth tendon. The fibres belonging to this tendon arise from the lower one-third or more of the anterior surface of the fibula, the lower part of the anterior surface of the interosseous membrane and the anterior crural intermuscular septum. The tendon passes behind the superior and within the loop of the inferior extensor retinaculum in company with the Extensor digitorum longus (fig. 656), and is inserted into the medial part of the dorsal surface of the base of the fifth metatarsal bone, but often spreads into a thin sheet which extends forwards along the medial border of the shaft of the bone. This muscle is sometimes wanting.

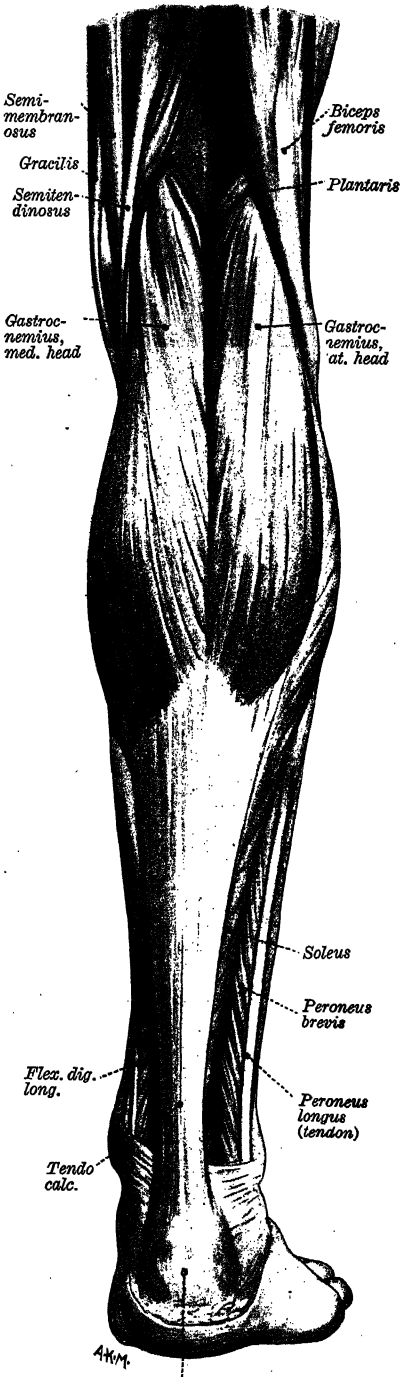
Actions.—The Peroneus tertius dorsiflexes the ankle-joint ; it also raises the lateral border of the foot, i.e. everts the foot.

Nerve-supply.—All the anterior crural muscles are supplied by the anterior tibial (deep peroneal) nerve (L. 4 and 5 and S. 1).

2. The Posterior Crural Muscles

The muscles of the back of the leg are subdivided into two groups—superficial and deep. Those of the superficial group constitute a powerful muscular mass, forming the calf of the leg. Their large size is one of the most characteristic features of the muscular apparatus in man, and bears a direct relation to his erect attitude and his mode of progression.

Fig. 651.—Muscles of calf; superficial layer. (From Quain's *Anatomy*, XI. Edition.)



Superficial Group (fig. 651)

Gastrocnemius. Soleus. Plantaris.

The **Gastrocnemius** (figs. 649, 651), which is the most superficial muscle of the group, forms the greater part of the calf. It arises by two heads, which are connected to the condyles of the femur by strong, flat tendons. The medial and larger head takes its origin from a depression at the upper and posterior part of the medial condyle behind the adductor tubercle, and from a rounded tubercle on the popliteal surface of the femur just above the medial condyle. The lateral head arises from an impression on the lateral surface of the lateral condyle and from the lower part of the corresponding supracondylar line. Both heads also arise from the subjacent part of the capsular ligament of the knee-joint. Each head spreads out into a tendinous expansion which covers the posterior surface of the corresponding part of the muscle. From the anterior surfaces of these tendinous expansions, muscular fibres are given off; those of the medial head extending lower than those of the lateral. The two heads remain separate and their fibres are inserted into a broad aponeurosis which is developed on the anterior surface of the muscle. The aponeurosis, gradually contracting, unites with the tendon of the Soleus, and forms with it the *tendo calcaneus*, p. 644.

Relations.—The fascia cruris separates the *superficial surface* of the muscle from the short saphenous vein, and the sural communicating and sural nerves; the lateral popliteal nerve crosses the lateral head of the muscle, lying partly under cover of Biceps femoris. The *deep surface* is in relation with the oblique posterior ligament of the knee-joint, the Popliteus, Soleus, Plantaris, popliteal vessels and medial popliteal nerve. A bursa which, in some cases, communicates with the cavity of the knee-joint is placed in front of the tendon of the medial head. The tendon of the lateral head sometimes contains a sesamoid fibrocartilage or bone, where it plays over the corresponding condyle; and one is occasionally found in the tendon of the medial head.

Nerve-supply.—The Gastrocnemius is supplied by the medial popliteal (tibial) nerve (S. 1 and 2).

Actions.—Acting from above the Gastrocnemius plantar-flexes the ankle-joint; acting from below it flexes the knee-joint.

The **Soleus** (figs. 649, 651) is a broad flat muscle situated immediately in front of the Gastrocnemius. It arises by tendinous fibres from the back of the head, and from the upper one-fourth of the posterior surface of the shaft of the fibula; from the soleal line (popliteal line) and the middle one-third of the medial border of the tibia; and from a fibrous band which stretches between

the tibia and fibula, and arches over the popliteal vessels and medial popliteal (tibial) nerve. The muscular fibres end in a flat tendon which covers the posterior surface of the muscle, and, gradually becoming thicker and narrower, joins with the tendon of the Gastrocnemius, and forms with it the tendo calcaneus.

Relations.—Its *superficial surface* is in relation with the Gastrocnemius and Plantaris; its *deep surface*, with the Flexor digitorum longus, Flexor hallucis longus, Tibialis posterior, and posterior tibial vessels and nerve, from all of which it is separated by the deep transverse fascia of the leg.

Nerve-supply.—The Soleus is supplied by the medial popliteal nerve (S. 1 and 2).

Actions.—The Soleus is a plantar-flexor of the ankle-joint; in standing, the Soleus, taking its fixed point from below, steadies the leg on the foot.

The Gastrocnemius and Soleus form a muscular mass which is occasionally described as the *Triceps suræ*; its tendon of insertion is the tendo calcaneus.

The **tendo calcaneus** (fig. 651), the common tendon of the Gastrocnemius and Soleus, is the thickest and strongest tendon in the body. It is about 15 cm. long, and begins near the middle of the leg, but its anterior surface receives fleshy fibres from the Soleus, almost to its lower end. It gradually narrows and thickens until it reaches a level about 4 cm. above the calcaneum; below this it expands and is inserted into the middle of the posterior surface of the calcaneum, a bursa being interposed between the tendon and the upper part of this surface.

Actions.—The muscles of the calf are the chief plantar-flexors of the ankle-joint. They possess considerable power, and are called into use in standing, walking, dancing and leaping; hence they are usually of large size. In walking, these muscles raise the heel from the ground; the body being thus supported on the raised foot, the opposite limb can be carried forwards.

The **Plantaris** (fig. 651) arises from the lower part of the lateral supracondylar line, and from the oblique posterior ligament of the knee-joint. It forms a small, fusiform belly, from 7 cm. to 10 cm. long; this ends in a long slender tendon, which crosses obliquely between the Gastrocnemius and Soleus and runs along the medial border of the tendo calcaneus to be inserted with it into the posterior part of the calcaneum. This muscle is sometimes double, and at other times wanting. Occasionally, its tendon is lost in the flexor retinaculum (laciniate ligament), or in the fascia of the leg.

Nerve-supply.—The Plantaris is supplied by the medial popliteal (tibial) nerve (L. *4* and 5 and S. 1).

Actions.—The Plantaris is the rudiment of a large muscle, the tendon of which in some of the lower animals is inserted into the plantar aponeurosis: in man it is an accessory to the Gastrocnemius, plantar-flexing the ankle-joint if the foot be free, or flexing the knee-joint if the foot be fixed.

Deep Group (fig. 652).

Popliteus.	Flexor digitorum longus.
Flexor hallucis longus.	Tibialis posterior.

The **deep transverse fascia** of the leg is a septum between the superficial and deep muscles of the back of the leg. At the sides it is connected to the medial margin of the tibia and the posterior border of the fibula. Above, where it is thick and dense, it is attached to the soleal ridge of the tibia and to the fibula, below and medial to the origin of the Soleus. Between these two attachments it is continuous with the fascia covering the Popliteus and receives an expansion from the tendon of the Semimembranosus; it is thin in the middle of the leg; but below, where it covers the tendons passing behind the malleoli, it is thick and continuous with the flexor retinaculum and the superior peroneal retinaculum.

The **Popliteus** (fig. 652) is a flat, triangular muscle, which forms the floor of the lower part of the popliteal fossa. It arises by a strong tendon about 2·5 cm. long, from a depression at the anterior part of the groove on the lateral condyle of the femur, and to a small extent from the oblique posterior ligament of the knee-joint. It is inserted into the medial two-thirds of the triangular area above the soleal line (popliteal line) on the posterior surface of the shaft of the tibia, and into the tendinous expansion covering the muscle.

Relations.—Its tendon of origin is intracapsular and is covered by the lateral ligament of the knee, and the tendon of the Biceps femoris (fig. 566). Invested on its deep surface by the synovial membrane, it grooves the posterior border of the lateral semilunar cartilage and the adjoining part of the tibia, and emerges from under cover of the posterior band of the arcuate ligament (fig. 556). On the floor of the popliteal fossa it is covered by a strong layer of fascia which is derived for the most part from the tendon of the Semimembranosus.

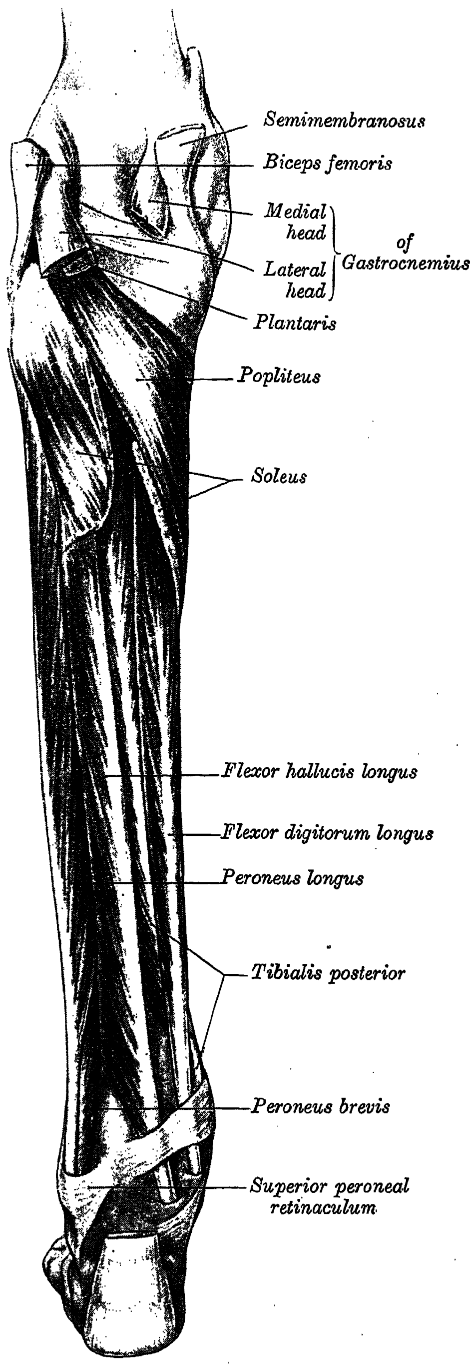


FIG. 652.—The left posterior crural muscles. Deep group.

Nerve-supply.—The Popliteus is supplied by the medial popliteal (tibial) nerve (L. *4* and *5* and S. 1).

Actions.—The Popliteus flexes the knee-joint; when the joint is flexed, it rotates the tibia medially. It is usually regarded as the muscle which 'unlocks' the joint at the beginning of flexion of the fully extended knee-joint (p. 501).

The **Flexor hallucis longus** (figs. 652, 655) is situated on the fibular side of the leg. It arises from the inferior two-thirds of the posterior surface of the shaft of the fibula, with the exception of about 2·5 cm. at its lowest part; from the lower part of the posterior surface of the interosseous membrane; from the posterior crural intermuscular septum, and from the fascia covering the Tibialis posterior, which it overlaps to a considerable extent. The fibres pass obliquely downwards and backwards, and end in a tendon which occupies nearly the whole length of the posterior surface of the muscle. This tendon lies in a groove which crosses the posterior surface of the lower end of the tibia, the posterior surface of the talus, and the under surface of the sustentaculum tali of the calcaneum (figs. 653, 656). In the sole of the foot it runs forwards between the two heads of the Flexor hallucis brevis, and is inserted into the plantar surface of the base of the distal phalanx of the great toe. The grooves on the talus and calcaneum which contain the tendon of the muscle are converted by tendinous fibres into a canal, which is lined by a synovial sheath. As the tendon passes forwards in the sole of the foot, it is situated above, and crosses from the lateral to the medial side of, the tendon of the Flexor digitorum longus, to which it is connected by a fibrous slip. This slip varies considerably in size; it is usually

distributed to the tendons for the second and third toes, but is sometimes restricted to that for the second, and occasionally is distributed to the tendon for the fourth toe, in addition.

Relations.—Its *superficial surface* is in relation with the Soleus and tendo calcaneus, from which it is separated by the deep transverse fascia; its *deep surface*, with the fibula, Tibialis posterior, the peroneal vessels, the lower part of the interosseous membrane, and the ankle-joint; its *lateral border*, with the Peronei; its *medial border*, with the Tibialis posterior, posterior tibial vessels and nerve.

Nerve-supply.—The Flexor hallucis longus is supplied by the posterior tibial nerve (L. 5 and S. 1 and 2).

Actions.—The Flexor hallucis longus flexes the great toe, and, continuing its action, plantar-flexes the ankle-joint.

The **Flexor digitorum longus** (fig. 652) is situated on the tibial side of the leg. Its upper part is thin and pointed, but the muscle gradually increases in size as it descends. It arises from the posterior surface of the shaft of the tibia, medial to the tibial origin of the Tibialis posterior; this origin extends from just below the soleal line (popliteal line) to within 7 cm. or 8 cm. of the lower extremity of the bone; it also arises from the fascia covering the Tibialis posterior. The fibres end in a tendon which runs nearly the whole length of the posterior surface of the muscle. This tendon gradually crosses the Tibialis posterior and passes behind the medial malleolus, in a groove common to it and the Tibialis posterior, but separated from the latter by a fibrous septum; each tendon being contained in a special compartment lined by a separate synovial sheath. It passes obliquely forwards and laterally, in contact with the medial side of the sustentaculum tali (fig. 653) and deep to the flexor retinaculum (laciniate ligament) and enters the sole of the foot (fig. 662), where it crosses below (i.e. superficial to) the tendon of the Flexor hallucis longus, and receives from it a strong slip. It then expands and is joined by the Flexor digitorum accessorius (Quadratus plantæ), and finally divides into four tendons, which are inserted into the plantar surfaces of the bases of the distal phalanges of the second, third, fourth, and fifth toes, each tendon passing through an opening in the corresponding tendon of the Flexor digitorum brevis opposite the base of the proximal phalanx.

Relations.—In the leg its *superficial surface* is in relation with the deep transverse fascia, which separates it from the Soleus, and, distally, with the posterior tibial vessels and nerve; its *deep surface*, with the tibia and Tibialis posterior. In the foot, it is covered by the Abductor hallucis and Flexor digitorum brevis, and crosses superficial to the Flexor hallucis longus.

Nerve-supply.—The Flexor digitorum longus is supplied by the posterior tibial nerve (L. 5 and S. 1).

Actions.—The Flexor digitorum longus flexes the phalanges of the toes, and in continued action plantar-flexes the ankle-joint. In consequence of the oblique direction of its tendons it draws the toes medially, but this is counteracted by the Flexor digitorum accessorius (Quadratus plantæ), which is inserted into the lateral side of the tendon.

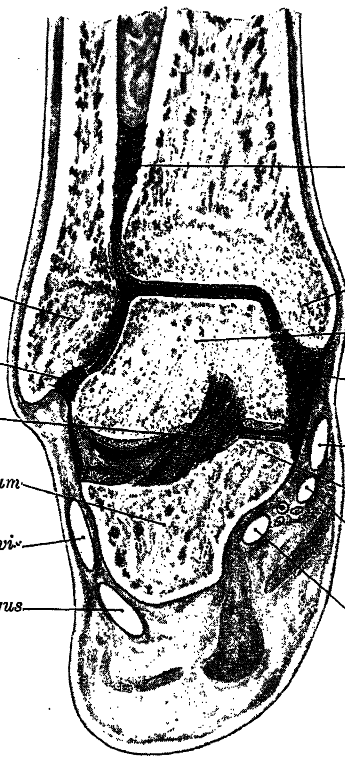
Both the Flexor hallucis longus and the Flexor digitorum longus play important parts in maintaining the longitudinal arch of the foot (p. 517).

The **Tibialis posterior** (figs. 649, 652) takes origin between the Flexor hallucis longus and Flexor digitorum longus, and is overlapped by both muscles, but especially by the Flexor hallucis longus; it is the deepest muscle on the back of the leg. It begins above by two pointed processes, separated by an angular interval through which the anterior tibial vessels pass to the front of the leg. It arises from the posterior surface of the crural interosseous membrane, with the exception of its lowest part; from the lateral portion of the posterior surface of the shaft of the tibia, between the commencement of the soleal line above and the junction of the middle with the lower one-third of the shaft below; and from the upper two-thirds of the medial part of the posterior surface of the fibula; some fibres also arise from the deep transverse fascia, and from the intermuscular septa separating it from the adjacent muscles. In the lower one-fourth of the leg its tendon passes in front of (i.e. deep to) that of the Flexor digitorum longus

and lies with it in a groove behind the medial malleolus, but enclosed in a separate sheath; it next passes deep to the flexor retinaculum (laciniate ligament) and superficial to the deltoid ligament (fig. 653) into the foot, and then below the plantar calcaneonavicular ligament, where it contains a sesamoid fibrocartilage. It is inserted into the tuberosity of the navicular bone, and gives off fibrous slips, one of which passes backwards and is attached to the sustentaculum tali of the calcaneum, while others pass forwards and laterally and are fixed to the three cuneiform bones, the cuboid bone, and the bases of the second, third and fourth metatarsal bones (fig. 569).

Relations.—Its *superficial surface* is in relation with the Soleus, from which it is separated by the deep transverse fascia, the Flexor digitorum longus, the Flexor hallucis longus, the

FIG. 653.—A coronal section through the left ankle and talocalcanean joints.



posterior tibial vessels, nerve, and the peroneal vessels; its *deep surface* with the interosseous membrane, the tibia, fibula and ankle-joint.

Nerve-supply.—The Tibialis posterior is supplied by the posterior tibial nerve (L. 5 and S. 1).

Actions.—The Tibialis posterior plantar-flexes the ankle-joint; it also pulls up the medial border of the foot, i.e. inverts the foot. In the sole of the foot its tendon lies inferomedial to the plantar calcaneonavicular ligament, and, together with its additional slips of insertion, is an important factor in maintaining the longitudinal arch of the foot (p. 517).

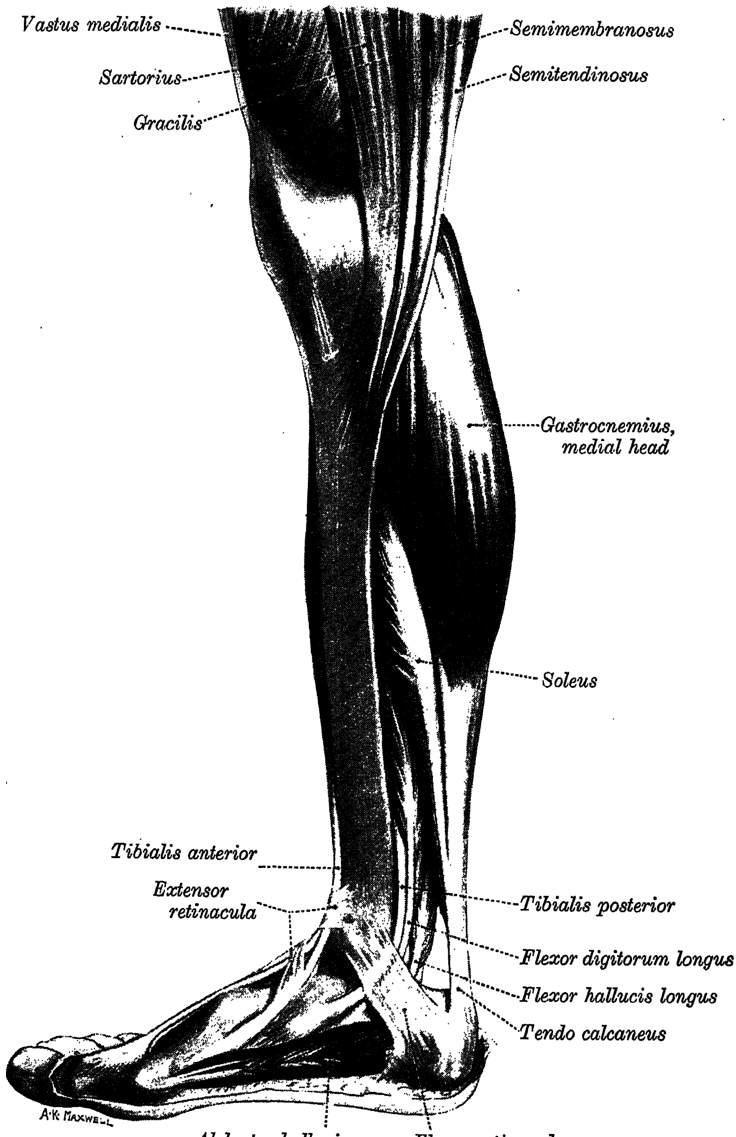
3. The Lateral Crural Muscles.

Peroneus longus. Peroneus brevis.

The **Peroneus longus** (figs. 649, 651, 652), which is the more superficial of the two muscles, is situated at the upper part of the lateral side of the leg. It arises from the head and upper two-thirds of the lateral surface of the shaft of the fibula, from the deep surface of the fascia cruris, and from the anterior and posterior crural intermuscular septa: occasionally also by a few fibres from

the lateral condyle of the tibia. Between its attachments to the head and body of the fibula, there is a gap through which the lateral popliteal (common peroneal) nerve passes. It ends in a long tendon, which runs behind the lateral malleolus, in a groove common to it and the tendon of the Peroneus brevis, behind which it lies; the groove is converted into a canal by the superior

FIG. 654.—The muscles of the right leg, viewed from the medial side. (From Quain's *Anatomy*, XI. Edition.)



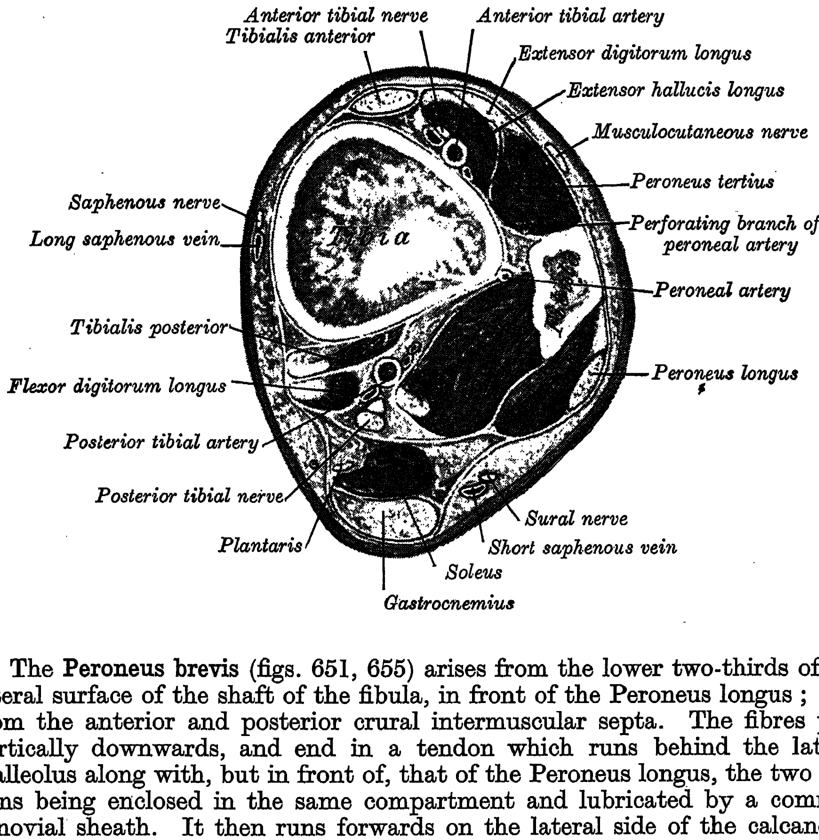
peroneal retinaculum, and the tendons in it are contained in a common synovial sheath. The tendon then runs obliquely forwards across the lateral side of the calcaneum, below the peroneal tubercle and the tendon of the Peroneus brevis, and under cover of the inferior peroneal retinaculum; it crosses the lateral side of the cuboid bone, and then runs on the under surface of that bone in a groove which is converted into a canal by the long plantar ligament (fig. 663). It crosses the sole of the foot obliquely, and is inserted by two slips into (*a*) the lateral side of the base of the first metatarsal bone and (*b*) the lateral side of the medial cuneiform bone; occasionally a third slip is attached to the

base of the second metatarsal bone. The tendon changes its direction at two points: (*a*) below the lateral malleolus, (*b*) on the cuboid bone; in both of these situations it is thickened, and, in the latter, a sesamoid fibrocartilage (sometimes a bone) is usually developed in its substance.

Nerve-supply.—The Peroneus longus is supplied by the musculocutaneous (superficial peroneal) nerve (L. *4* and 5 and S. 1).

Actions.—The Peroneus longus plantar-flexes the ankle-joint and everts the foot, so long as it is not bearing weight. As a consequence of the oblique direction of its tendon across the sole it is an important agent in maintaining the transverse and lateral longitudinal arches of the foot. In the active erect posture (p. 517) it produces depression and medial rotation of the first metatarsal and medial cuneiform bones and so enables the inverted foot to remain plantigrade. Taking its fixed point below, the Peroneus longus serves to steady the leg on the foot; this is especially the case in standing on one leg, when the tendency of the superincumbent weight is to throw the leg medially.

FIG. 655.—A transverse section through the leg, 6 cm. above the tip of the medial malleolus.



The **Peroneus brevis** (figs. 651, 655) arises from the lower two-thirds of the lateral surface of the shaft of the fibula, in front of the Peroneus longus; and from the anterior and posterior crural intermuscular septa. The fibres pass vertically downwards, and end in a tendon which runs behind the lateral malleolus along with, but in front of, that of the Peroneus longus, the two tendons being enclosed in the same compartment and lubricated by a common synovial sheath. It then runs forwards on the lateral side of the calcaneum above the peroneal tubercle (trochlear process) and the tendon of the Peroneus longus, and is inserted into the tubercle on the base of the fifth metatarsal bone, on its lateral side.

On the lateral surface of the calcaneum the tendons of the Peronei longus et brevis occupy separate, osseo-aponeurotic canals formed by the calcaneum and the inferior peroneal retinaculum; each tendon is enveloped by a forward prolongation of the common synovial sheath.

Nerves.—The Peroneus brevis is supplied by the musculocutaneous (superficial peroneal) nerve (L. *4* and 5 and S. 1).

Action.—The Peroneus brevis plantar-flexes the foot upon the leg, and assists the Peroneus longus to evert the foot.

Applied Anatomy.—Rigidity and contraction of the tendons of the various muscles of the leg give rise to one or other of the kinds of deformity known as *club foot.* The most simple and common deformity, and one that is rarely, if ever, congenital, is *talipes equinus,* the heel being raised by the rigidity and contraction of the Gastrocnemius so that the patient walks upon the ball of the foot. In *talipes varus,* the foot is forcibly adducted and the medial side of the sole raised, sometimes to a right angle with the ground, by the action of the Tibiales anterior et posterior. In *talipes valgus,* the lateral edge of the foot is raised by the Peronei, and the patient walks on the medial side of the foot. In *talipes calcaneus* the toes are raised by the extensor muscles, the heel is depressed and the patient walks upon it. Other varieties of deformity are met with, as *talipes equinovarus, equinovalgus* and *calcaneovalgus,* names which sufficiently indicate their nature. Of these, talipes equinovarus is the most common congenital form; the heel is raised by the tendo calcaneus, the medial border of the foot drawn upwards by the Tibialis anterior, the anterior two-thirds twisted medially by the Tibialis posterior, and the arch increased by the contraction of the plantar aponeurosis, so that the patient walks on the middle of the lateral border of the foot.

Rupture of a few fibres of the Gastrocnemius, or rupture of the Plantaris tendon, not uncommonly occurs, especially in men somewhat advanced in life, from some sudden exertion, and frequently occurs during the game of lawn-tennis, and is hence known as 'lawn-tennis leg.' The accident is accompanied by a sudden pain, and produces a sensation as if the individual had been struck a violent blow on the part. The tendo calcaneus is also sometimes ruptured. It is stated that John Hunter ruptured his tendo calcaneus while dancing, at the age of forty.

THE FASCIA ROUND THE ANKLE

As the tendons of the muscles of the leg cross the ankle-joint on their way to the foot, they are bound down by localised thickenings in the deep fascia which constitute retinacular bands comparable, both in mode of formation and in function, to the flexor and extensor retinacula of the wrist (p. 609). They comprise the superior and inferior extensor retinacula (transverse and cruciate crural ligaments), the flexor retinaculum (laciniate ligament), and the superior and inferior peroneal retinacula.

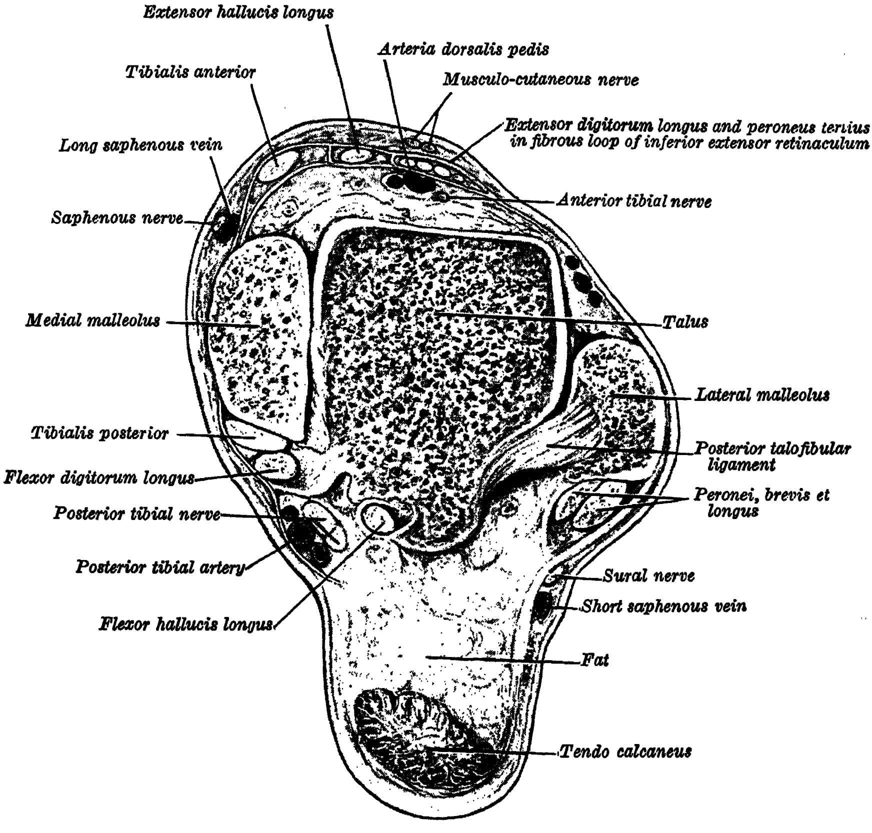
The **superior extensor retinaculum** (transverse crural ligament) (figs. 650, 657) binds down the tendons of the Tibialis anterior, Extensor hallucis longus, Extensor digitorum longus and Peroneus tertius, as they descend on the front of the ankle-joint; the anterior tibial vessels and nerve also pass under cover of it. It is attached laterally to the lower end of the anterior border of the fibula, and medially to the anterior border of the tibia; above, it is continuous with the deep fascia of the leg.

The **inferior extensor retinaculum** (cruciate crural ligament) (figs. 656, 657) is a Y-shaped band placed in front of the ankle-joint. The stem of the Y is attached to the upper surface of the calcaneum, in front of the sulcus calcanei, and passes medially, forming a strong loop which encloses the tendons of the Peroneus tertius and the Extensor digitorum longus. From the extremity of this loop two diverging bands pass medially to complete the Y. The *upper band* consists of two distinct lamellæ. The deep lamella passes behind the tendons of the Extensor hallucis longus and the Tibialis anterior, but in front of the anterior tibial vessels and nerve, to reach the tibial malleolus. The superficial lamella crosses in front of the tendon of the Extensor hallucis longus and is then firmly connected to the deep lamella; it may or may not be continued in front of the tendon of the Tibialis anterior to reach the tibia. The *lower band* extends downwards and medially to be attached to the plantar aponeurosis; it crosses the tendons of the Extensor hallucis longus and Tibialis anterior, the arteria dorsalis pedis and the terminal branches of the anterior tibial (deep peroneal) nerve. From the deep surface of the loop which encloses the tendons of the Peroneus tertius and the Extensor digitorum longus, a distinct band of fibres passes medially between the constituent layers of the interosseous talocalcanean ligament (p. 509) to gain attachment to the upper surface of the calcaneum and the under surface of the neck of the talus.*

* E. Barclay Smith, *Journal of Anatomy,* vol. xxx. 1896. T. T. Stamm, *Ibid.* vol. lxvi. 1931.

The **flexor retinaculum** (laciniate ligament) (fig. 654) extends from the tibial malleolus above to the margin of the calcaneum below; its upper border is continuous with the deep transverse fascia of the leg, its lower with the plantar aponeurosis and the fibres of origin of the Abductor hallucis muscle. It converts a series of bony grooves in this situation into canals for the passage of the tendons of the flexor muscles into the sole of the foot, and also affords protection to the posterior tibial vessels and nerve as they enter the sole of the foot. From the medial to the lateral side these structures lie in the following order: tendon of the Tibialis posterior, tendon of the Flexor digitorum longus, posterior tibial vessels and nerve, and tendon of the Flexor hallucis longus (fig. 656).

FIG. 656.—Transverse section through the lower part of the ankle-joint.



The **peroneal retinacula** are fibrous bands which retain the tendons of the Peroneus longus and brevis in position as they cross the lateral side of the ankle. The *superior retinaculum* (fig. 652) extends from the back of the lateral malleolus to the deep transverse fascia of the leg and the lateral surface of the calcaneum. The *inferior retinaculum* is continuous in front with the inferior extensor retinaculum; behind it is attached to the lateral surface of the calcaneum; some of its fibres are fixed to the peroneal tubercle of the calcaneum, forming a septum between the tendons of the Peroneus longus and brevis.

The synovial sheaths of the tendons round the ankle.—The tendons crossing the ankle-joint are enclosed in synovial sheaths. On the *front* of the ankle (fig. 657) the sheath for the Tibialis anterior extends from the upper margin of the upper extensor retinaculum to the interval between the diverging limbs of the lower retinaculum; those for the Extensor digitorum longus and Extensor hallucis longus reach upwards to just above the level of the malleoli, the former

being the higher. The sheath of the Extensor hallucis longus is prolonged on to the base of the first metatarsal bone, while that of the Extensor digitorum longus reaches only to the level of the base of the fifth metatarsal bone. On the *medial side* of the ankle (fig. 658) the sheath for the Tibialis posterior extends

FIG. 657.—The synovial sheaths of the tendons round the right ankle. Lateral aspect. (From a specimen prepared by J. C. B. Grant.)

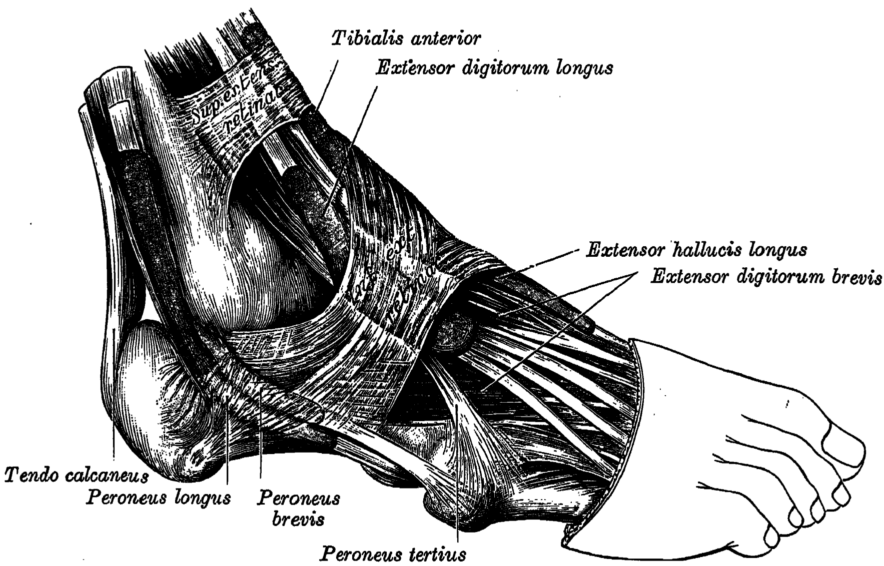
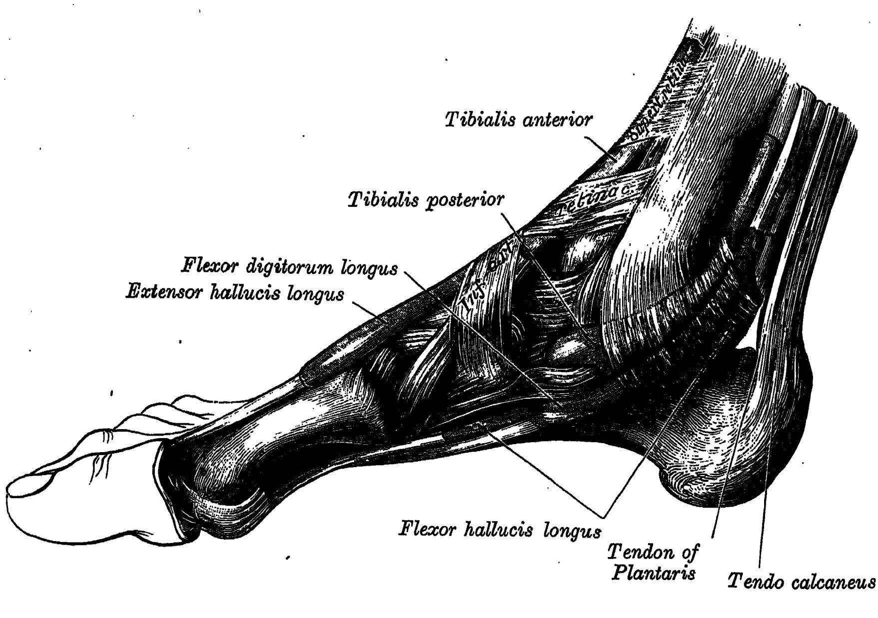


FIG. 658.—The synovial sheaths of the tendons round the right ankle. Medial aspect. (From a specimen prepared by J. C. B. Grant.)



for about 4 cm. above the malleolus ; below, it ends just short of the insertion of the tendon into the tuberosity of the navicular bone. The sheath for the Flexor hallucis longus reaches up to the level of the malleolus, while that for the Flexor digitorum longus goes slightly higher ; the former is continued to the base of the first metatarsal bone, but the latter ends opposite the navicular bone. On the *lateral side* of the ankle (fig. 657) a sheath, the upper part of

which is single and the lower part double, encloses the Peroneus longus and brevis. It extends upwards for about 4 cm. above the tip of the malleolus, and downwards and forwards for about the same distance.

IV. The Muscles of the Foot

1. The Dorsal Muscle of the Foot

Extensor digitorum brevis.

The **fascia** on the dorsum of the foot (fascia dorsalis pedis) is a thin, membranous layer, continuous above with the inferior extensor retinaculum; at the sides of the foot it blends with the plantar aponeurosis; anteriorly it ensheathes the tendons on the dorsum of the foot.

The **Extensor digitorum brevis** (figs. 650, 657) is a thin muscle, which arises from the forepart of the upper and lateral surface of the calcaneum, in front of the groove for the Peroneus brevis; from the interosseous talocalcaneal ligament, and the stem of the inferior extensor retinaculum. It passes obliquely forwards and medially across the dorsum of the foot, and ends in four tendons. The medial part of the muscle is usually a more or less distinct slip ending in a tendon which crosses the dorsalis pedis artery and is inserted into the dorsal surface of the base of the proximal phalanx of the great toe; it is sometimes described as a separate muscle—the *Extensor hallucis brevis*. The other three tendons are inserted into the lateral sides of the tendons of the Extensor digitorum longus of the second, third and fourth toes.

Nerve-supply.—The Extensor digitorum brevis is supplied by the lateral terminal branch of the anterior tibial (deep peroneal) nerve (L. 4 and 5 and S. 1).

Actions.—The Extensor digitorum brevis extends the phalanges of the four toes into which it is inserted, but, in the great toe, acts only on the first phalanx.

2. The Plantar Muscles of the Foot

The **plantar aponeurosis** (fig. 659) is of great strength, and consists of white fibres disposed, for the most part, longitudinally: it is divided into central, lateral, and medial portions.

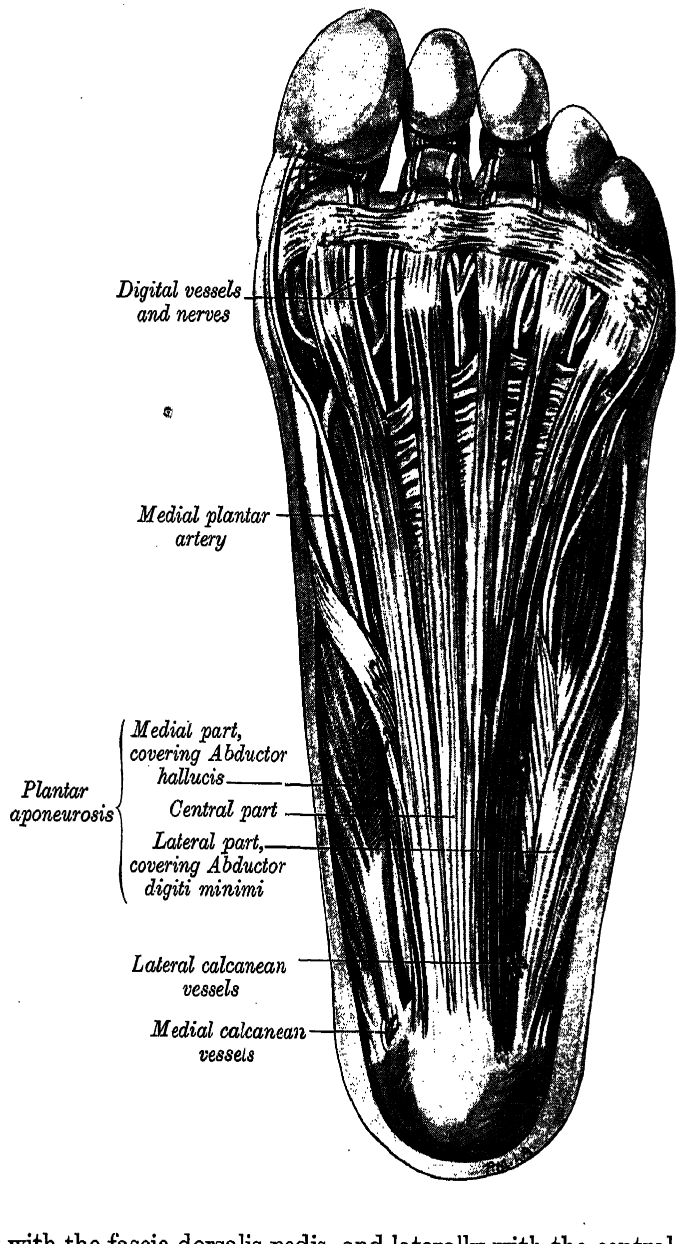
The *central portion* is the thickest: it is narrow behind, and attached to the medial tubercle of the calcaneum posterior to the origin of the Flexor digitorum brevis; it becomes broader and thinner in front, and divides near the heads of the metatarsal bones into five processes, one for each toe. Each of these processes splits opposite the metatarsophalangeal joint into a superficial and a deep stratum. The superficial stratum is inserted into the skin of the transverse sulcus which separates the toes from the sole. The deep stratum divides into two slips which embrace the sides of the flexor tendons of the toes, and blend with the fibrous sheaths of these tendons and with the deep transverse ligaments of the sole, thus forming a series of arches through which the tendons of the short and long flexors pass to the toes. Through the intervals between the five processes the digital vessels and nerves and the tendons of the Lumbrical muscles are transmitted. At the point of division of the aponeurosis numerous transverse fasciculi bind the processes together, and connect them with the skin. The central portion of the plantar aponeurosis is continuous with the lateral and medial portions, and sends upwards, at the lines of junction, two vertical intermuscular septa, which separate the intermediate from the lateral and medial groups of plantar muscles; from these vertical septa thinner transverse septa are derived which separate the different layers of muscles. The deep surface of the central part of the aponeurosis gives origin behind to the Flexor digitorum brevis.

The *lateral portion* covers the under surface of the Abductor digiti minimi; it is thin in front and thick behind, where it forms a strong band between the

lateral tubercle of the calcaneum and the base of the fifth metatarsal bone ; it is continuous medially with the central portion, and laterally with the fascia on the dorsum of the foot.

The *medial portion* is thin, and covers the under surface of the Abductor hallucis ; it is continuous behind with the flexor retinaculum (laciniate ligament),

FIG. 659.—The plantar aponeurosis of the left foot.



medially with the fascia dorsalis pedis, and laterally with the central portion of the plantar aponeurosis.

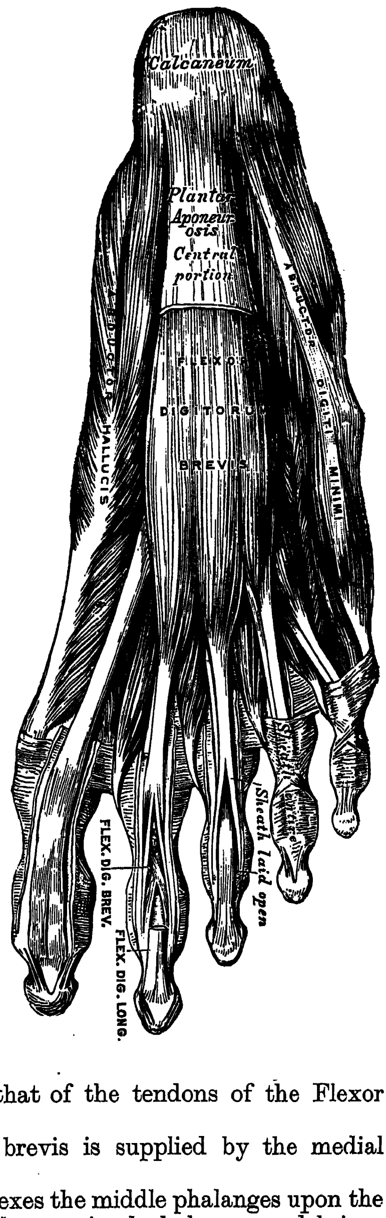
The muscles in the plantar region of the foot may be divided into medial, lateral and intermediate groups; but for descriptive purposes it is more convenient to group them in four layers, as met with in the course of dissection.

The First Layer (fig. 660)

Abductor hallucis. Flexor digitorum brevis.
Abductor digiti minimi.

All the muscles of this layer extend from the tubercles of the calcaneum to the toes, and therefore, together with the plantar aponeurosis, play a subsidiary part in maintaining the longitudinal arches of the foot.

FIG. 660.—The plantar muscles of the right foot. First layer.



The **Abductor hallucis** (fig. 660) lies along the medial border of the foot and covers the origins of the plantar vessels and nerves. It arises from the medial tubercle of the calcaneum, the flexor retinaculum (laciniate ligament), the plantar aponeurosis, and the intermuscular septum between it and the Flexor digitorum brevis. The fibres end in a tendon which is inserted, together with the medial tendon of the Flexor hallucis brevis, into the medial side of the base of the proximal phalanx of the great toe.

Nerve-supply.—The Abductor hallucis is supplied by the medial plantar nerve (L. 5 and S. 1).

Actions.—The Abductor hallucis flexes and abducts the proximal phalanx of the great toe.

The **Flexor digitorum brevis** (fig. 660) lies immediately above the central part of the plantar aponeurosis. Its deep surface is separated from the lateral plantar vessels and nerves by a thin layer of fascia. It arises by a narrow tendon from the medial tubercle of the calcaneum, from the central part of the plantar aponeurosis, and from the intermuscular septa between it and the adjacent muscles. It divides into four tendons, one for each of the four lesser toes. Opposite the bases of the proximal phalanges, each tendon divides into two slips, to allow of the passage of the corresponding tendon of the Flexor digitorum longus; the two slips then unite, partially decussate, and form a grooved channel for the reception of the tendon of the Flexor digitorum longus. The tendon divides again and is inserted into the sides of the middle phalanx about its middle. The mode of division of the tendons of the Flexor digitorum brevis, and of their insertion into the phalanges, is identical with that of the tendons of the Flexor digitorum sublimis in the hand.

Nerve-supply.—The Flexor digitorum brevis is supplied by the medial plantar nerve (L. 5 and S. 1 and 2).

Actions.—The Flexor digitorum brevis flexes the middle phalanges upon the proximal; continuing its action it flexes the proximal phalanges and brings the toes together.

The fibrous sheaths of the flexor tendons (fig. 660).—The terminal portions of the tendons of the long and short flexor muscles are contained in osseo-aponeurotic canals similar in their arrangement to those in the fingers. These

canals are bounded above by the phalanges, and below by fibrous bands which arch across the tendons, and are attached on either side to the margins of the phalanges. Opposite the shafts of the proximal and middle phalanges the fibrous bands (*vaginal ligaments*) are strong, and the fibres are transverse ; but opposite the joints they are much thinner, and the fibres are directed obliquely. Each canal contains a synovial sheath, which is reflected on the contained tendons ; within this sheath *vincula tendinum* are arranged similarly to those of the fingers.

The **Abductor digiti minimi** (fig. 660) lies along the lateral border of the foot, and its medial margin is in relation with the lateral plantar vessels and nerve. It arises from the lateral and medial tubercles of the calcaneum, from the under surface of the bone between the processes, from the plantar aponeurosis, and from the intermuscular septum between it and the Flexor digitorum brevis. Its tendon glides over a smooth facet on the under surface of the base of the fifth metatarsal bone and is inserted, with the Flexor digiti minimi brevis, into the lateral side of the base of the proximal phalanx of the fifth toe.

Nerve-supply.—The Abductor digiti minimi is supplied by the lateral plantar nerve (S. 1 and 2).

Actions.—The Abductor digiti minimi flexes and abducts the proximal phalanx of the little toe.

The Second Layer (figs. 661, 662)

Flexor digitorum accessorius. Lumbricales.

The **Flexor digitorum accessorius** (Quadratus plantæ) (fig. 662) arises by two heads which are separated from each other by the long plantar ligament : the medial, and larger, head is muscular, and is attached to the medial concave surface of the calcaneum below the groove for the tendon of the Flexor hallucis longus ; the lateral head, flat and tendinous, arises from the calcaneum in front of the lateral tubercle and from the long plantar ligament. The two portions join at an acute angle, and end in a flattened band which is inserted into the superior surface and lateral margin of the tendon of the Flexor digitorum longus, forming a kind of groove in which the tendon is lodged. It usually sends slips to those tendons of the Flexor digitorum longus which pass to the second, third and fourth toes.

Nerve-supply.—The Flexor digitorum accessorius is supplied by the lateral plantar nerve (S. 1).

Actions.—The Flexor digitorum accessorius assists the Flexor digitorum longus and converts the oblique pull of the tendons of that muscle into a direct backward pull on the toes.

The **Lumbricales** (fig. 662) are four small muscles, accessory to the tendons of the Flexor digitorum longus, and numbered from the medial side of the foot ; they arise from these tendons, as far back as their angles of separation, and, with the exception of the first, which arises only from the medial border of the first tendon of the Flexor digitorum longus, each springs from two tendons. The muscles end in tendons which pass forwards and upwards on the medial sides of the four lesser toes, and are inserted into the expansions of the tendons of the Extensor digitorum longus on the dorsal surfaces of the proximal phalanges.

Nerve-supply.—The first Lumbrical is supplied by the medial plantar nerve (L. 5 and S. 1) ; the others by the deep branch of the lateral plantar nerve (S. 1 and 2).

Actions.—The Lumbricals flex the proximal phalanges and, by their insertions into the tendons of the Extensor digitorum longus, extend the middle and distal phalanges.

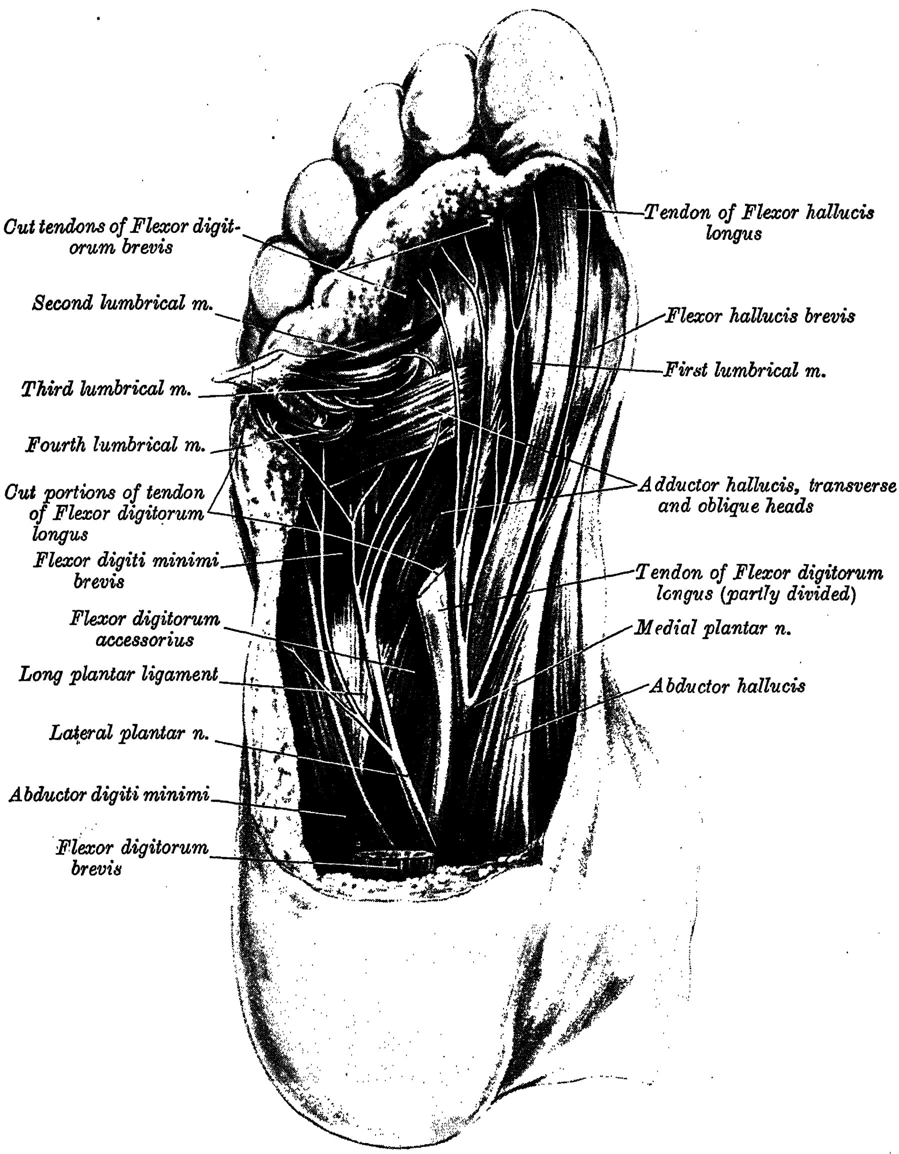
The Third Layer (figs. 661, 663)

Flexor hallucis brevis. Adductor hallucis.
Flexor digiti minimi brevis.

The **Flexor hallucis brevis** (fig. 663) arises by a pointed, tendinous process from the medial part of the under surface of the cuboid bone, behind the groove

for the Peroneus longus tendon, from the contiguous portion of the lateral cuneiform bone, and from the part of the tendon of the Tibialis posterior which is attached to that bone. It divides into a medial and a lateral portion, and the tendons of these are inserted into the corresponding sides of the base of the proximal phalanx of the great toe, a sesamoid bone being present in each

Fig. 661.—The muscles of the sole of the foot and their nerves of supply.



Most of the Flexor digitorum brevis has been removed. The Flexor digitorum longus has been divided partially, and its distal end has been turned forwards together with the second, third and fourth Lumbrical muscles.

tendon at its insertion. The medial portion is blended with the Abductor hallucis previous to its insertion ; the lateral, with the Adductor hallucis. The lateral portion of the Flexor hallucis brevis is sometimes described as the *first plantar interosseous* muscle.

Nerve-supply.—The Flexor hallucis brevis is supplied by the medial plantar nerve (L. 5 and S. 1).

Action.—The Flexor hallucis brevis flexes the proximal phalanx of the great toe.

The **Adductor hallucis** (fig. 663) arises by two heads—oblique and transverse. The *oblique head* springs from the bases of the second, third and fourth metatarsal bones, and from the sheath of the tendon of the Peroneus longus, and is inserted, together with the lateral portion of the Flexor hallucis brevis,

Fig. 662.—The plantar muscles of the right foot. Second layer.

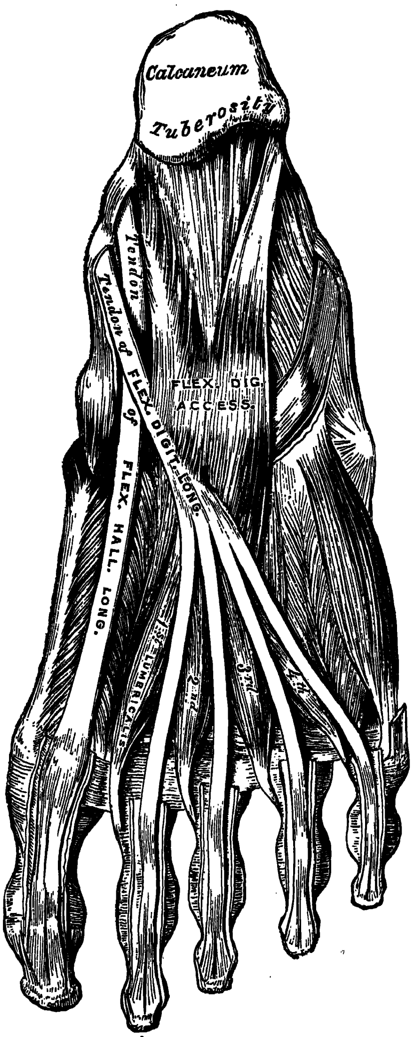
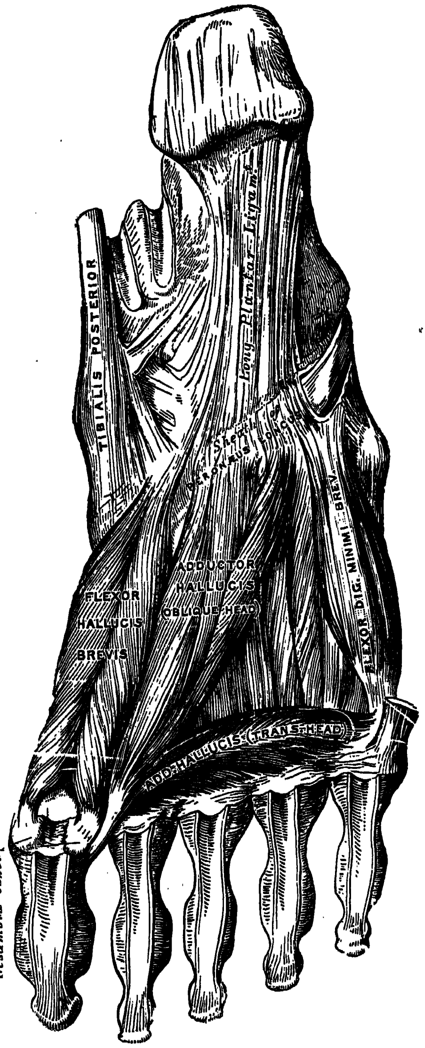


Fig. 663.—The plantar muscles of the right foot. Third layer.



into the lateral side of the base of the proximal phalanx of the great toe. The *transverse head*, a narrow, flat fasciculus, arises from the plantar metatarsophalangeal ligaments of the third, fourth and fifth toes (sometimes only from the third and fourth), and from the deep transverse ligaments of the sole. It is inserted into the lateral side of the base of the proximal phalanx of the great toe, its tendon of insertion blending with that of the oblique head.

Nerve-supply.—The Adductor hallucis is supplied by the deep branch of the lateral plantar nerve (S. 1 and 2).

Actions.—The oblique head of the Adductor hallucis is chiefly concerned in adducting, but it also assists in flexing, the great toe; the transverse head approximates the toes and thus increases the curve of the transverse arch of the metatarsus.

The **Flexor digiti minimi brevis** (fig. 663) arises from the medial part of the plantar surface of the base of the fifth metatarsal bone, and from the sheath of the Peroneus longus ; its tendon is inserted into the lateral side of the base of the proximal phalanx of the fifth toe. Occasionally a few of the deeper fibres are inserted into the lateral part of the distal one-half of the fifth metatarsal bone ; these are described by some as a distinct muscle—the *Opponens digiti minimi.*

Nerve-supply.—The Flexor digiti minimi brevis is supplied by the superficial branch of the lateral plantar nerve (S. 1 and 2).

Action.—The Flexor digiti minimi brevis flexes the little toe.

The Fourth Layer

Interossei.

The **Interossei** in the foot are similar to those in the hand, but are grouped on each side of the middle line of the *second* digit, instead of that of the *third.* They consist of a dorsal and a plantar set.

The **Interossei dorsales** (fig. 664), four in number, are situated between the metatarsal bones. They are bipennate muscles, each arising by two heads from the adjacent sides of the metatarsal bones between which it is placed ; their tendons are inserted into the bases of the proximal phalanges, and into the aponeuroses of the tendons of the Extensor digitorum longus. The first is

FIG. 664.—The Interossei dorsales of the left foot. Dorsal aspect.

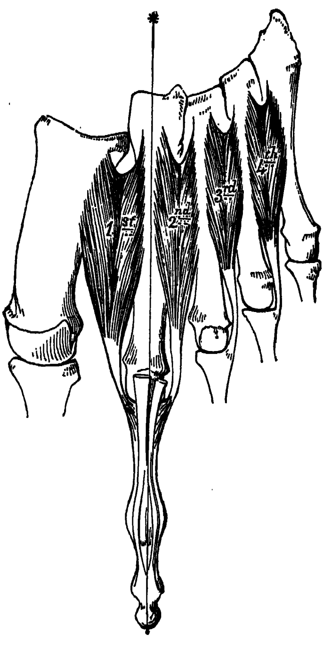
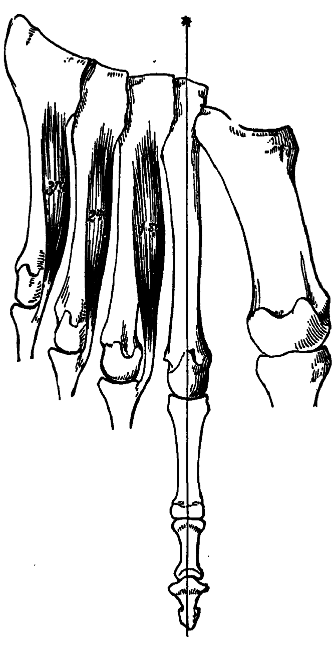


FIG. 665.—The Interossei plantares of the left foot. Plantar aspect.



inserted into the medial side of the second toe ; the other three into the lateral sides of the second, third, and fourth toes. In the angular interval between the heads of each of the three lateral muscles, one of the perforating arteries passes to the dorsum of the foot ; through the space between the heads of the first muscle the terminal part of the dorsalis pedis artery enters the sole of the foot.

The **Interossei plantares** (fig. 665), three in number, lie below rather than between the metatarsal bones, and each is connected with but one metatarsal bone. They arise from the bases and medial sides of the shafts of the third, fourth, and fifth metatarsal bones, and are inserted into the medial sides of the

bases of the proximal phalanges of the same toes, and into the aponeuroses of the tendons of the Extensor digitorum longus.

Nerve-supply.—The Dorsal and Plantar interossei are supplied by the deep branch of the lateral plantar nerve (S. 1 and 2), except those in the fourth interosseous space, which are supplied by the superficial branch of the same nerve. The first Dorsal interosseous frequently receives an extra filament from the medial branch of the anterior tibial nerve on the dorsum of the foot, and the second Dorsal interosseous a twig from the lateral branch of the same nerve.

Actions.—The Dorsal interossei are abductors from an imaginary line passing through the axis of the second toe, so that the first muscle draws the second toe medially, the second muscle draws the same toe laterally, and the third and fourth draw the third and fourth toes laterally. They assist in flexing the proximal and extending the middle and distal phalanges. The Plantar interossei adduct the third, fourth and fifth toes towards the imaginary line passing through the second toe, and, by means of their insertions into the aponeuroses of the Extensor tendons, assist in flexing the proximal phalanges and extending the middle and distal phalanges.

BLOOD VASCULAR SYSTEM

THE vascular system is divided for descriptive purposes into (*a*) the *blood-vascular system*, comprising the heart and blood-vessels through which the blood circulates ; and (*b*) the *lymphatic system*, consisting of lymph-glands and lymphatic vessels, through which a colourless fluid, termed the lymph, circulates.* The two systems communicate with each other and are intimately associated developmentally.

The heart, the central organ of the blood-vascular system, is situated within the thorax. It is a hollow, muscular organ, by the contraction of which the blood is pumped to all parts of the body through a complicated series of tubes, termed *arteries*. The arteries ramify extensively in their course throughout the body, and end in minute vessels, called *arterioles*, which open into a close-meshed network of microscopic vessels, named *capillaries*. After the blood has passed through the capillaries it is collected into a series of minute vessels, called *venules*, which join with one another to form *veins* : the veins unite with one another, and ultimately two large venous trunks, named the superior and inferior venæ cavæ, are formed which return the blood to the heart. While the blood is passing through the capillaries a transudation of certain of its fluid elements takes place into the tissue-spaces. In proportions which vary according to the metabolic conditions, this fluid is taken up partly by the capillaries by a process of reabsorption, and partly by the lymph vessels, which return it to the large veins at the root of the neck. The passage of the blood through the heart and blood-vessels is termed the *circulation* of the blood, of which the following is an outline.

The heart is divided into four chambers, of which two are receiving and two are distributing chambers. The right and left *atria* receive the blood from the great veins and expel it into the right and left *ventricles*. From the ventricles the blood is pumped into the arterial system and carried to the various organs of the body. Although each atrium communicates freely with the corresponding ventricle, the right and left chambers of the heart are separated from one another by partitions or *septa*, and they do not communicate with one another after birth in normal subjects. The superior and the inferior venæ cavæ bring to the right atrium blood which has become deoxygenated and has taken up carbon dioxide during its circulation through the tissues of the body. From the right atrium the blood passes into the right ventricle, by which it is expelled into the pulmonary artery to be conveyed to the right and left lungs. As it circulates through the pulmonary capillaries the blood is brought into close relationship with the air in the lungs, and it gives off some of its carbon dioxide content and acquires a fresh supply of oxygen. Re-collected by the pulmonary veins the freshly oxygenated blood is returned to the left atrium of the heart and passes into the left ventricle. With each beat of the heart the left ventricle pumps its contents into a large artery termed the aorta, which distributes blood through its numerous branches to all the tissues and organs of the body with the exception of the lungs.

The course of the blood from the left ventricle through the body generally to the right side of the heart constitutes the greater or *systemic* circulation, while its passage from the right ventricle through the lungs to the left side of the heart is termed the lesser or *pulmonary* circulation.

It is necessary, however, to point out that the blood which circulates through the spleen, pancreas, stomach, small intestine and the greater part of the large intestine is not returned directly from these organs to the heart, but is conveyed by the *portal vein* to the liver. In the liver this vein divides like an artery, and ultimately ends in capillary-like vessels (sinusoids), from which the rootlets of the *hepatic veins* arise ; the hepatic veins carry the blood into the inferior vena cava, which conveys it to the right atrium. This constitutes the *portal circulation*, and it will be understood that the blood supplied to the

* The blood and lymph are described on pp. 28 to 31.

above-named viscera passes through two sets of minute vessels before reaching the inferior vena cava: (1) the capillaries in the spleen, pancreas, stomach, etc., draining into the portal vein, and (2) the sinusoids in the liver, draining into the hepatic veins. The passage through two sets of capillaries enables the blood to take up products of digestion from the alimentary canal and to convey them to the liver cells, where sugar is stored in the form of glycogen.

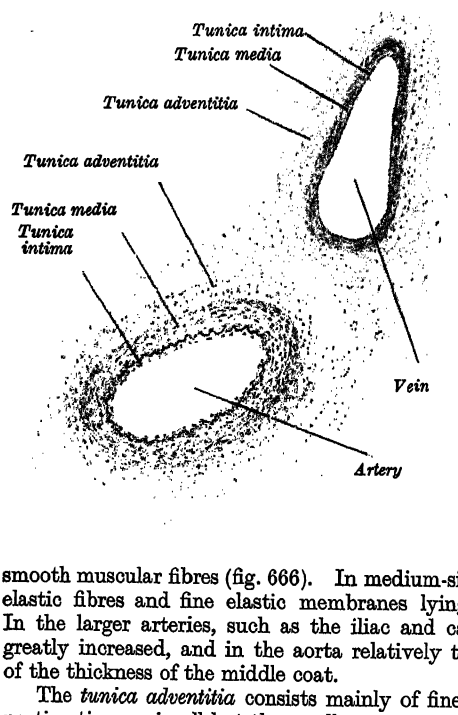
It should be stated that, in addition to the normal capillaries, communications exist between the smaller arteries and veins in the skin of the hands and feet.* These communications are of great importance in the regulation of body temperature, both local and general, as the communicating vessels are able to dilate or to become constricted and so determine the amount of flow through the capillaries at any given time.

THE STRUCTURE OF THE BLOOD-VESSELS

The arteries (figs. 666, 668).—The wall of an artery consists of three coats, viz. an internal or *tunica intima*, a middle or *tunica media*, and an external or *tunica adventitia*. The external coat is tougher than the other two, which are ruptured when a ligature is tied round the vessel, and, in virtue of their elasticity, become retracted from the site of the ligature.

The *tunica intima* consists of (*a*) an internal layer of flattened cells, (*b*) beneath these, a small quantity of loose connective tissue, and (*c*) an elastic lamina. The flattened endothelial cells are fusiform in shape with their long axes parallel to the long axes of the blood-vessels. Each cell possesses a nucleus, and is attached to adjacent cells by cement-substance which reduces silver nitrate. The connective tissue layer is very thin, and contains branched cells, and in the larger arteries, fine elastic fibres with some longitudinal unstriped muscular fibres (*musculo-elastic layer of intima*); this layer increases in thickness with increasing age. The elastic lamina is built up of longitudinally arranged elastic fibres fused together, and is usually fenestrated, having round or oval apertures at irregular intervals. In a transverse section of an artery it appears as a characteristic wavy line, owing to the contracted condition of the empty vessel.

FIG. 666.—A transverse section through an artery and a vein of a child aged 13 months. Stained with hæmatoxylin and eosin. ×20.



The *tunica media*, in the smaller and medium-sized arteries, consists principally of smooth muscular fibres arranged circularly round the vessel; the fibres have well-marked, rod-shaped nuclei. In the smallest arteries the middle coat is composed entirely of smooth muscular fibres (fig. 666). In medium-sized arteries (fig. 668) there are in addition elastic fibres and fine elastic membranes lying between the layers of muscular fibres. In the larger arteries, such as the iliac and carotid, the proportion of elastic tissue is greatly increased, and in the aorta relatively thick elastic laminæ form the greater part of the thickness of the middle coat.

The *tunica adventitia* consists mainly of fine and closely felted bundles of white connective tissue; in all but the smallest arteries it contains some elastic fibres. The elastic tissue is most abundant next the tunica media, and it is sometimes described as forming, between the adventitia and media, a special layer—the *tunica elastica externa*; this layer is most marked in arteries of medium size. In the largest vessels the external coat is relatively thin. From the medium-sized to the smaller arteries it diminishes gradually in thickness; in the smallest arteries the elastic fibres are wanting, and the connective tissue, of which the coat is composed, becomes more homogeneous the nearer it approaches the capillaries, and is gradually reduced to a thin membranous envelope, which finally disappears.

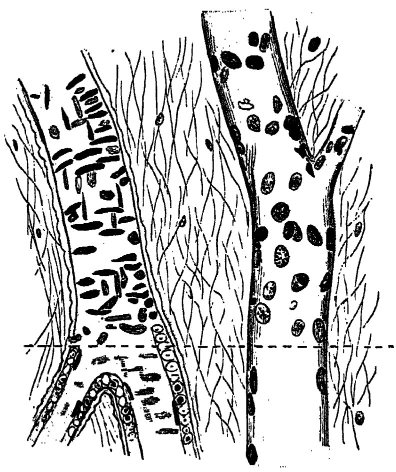
* See Hoyes, W., *Archiv f. Mikroskop. Anat.*, Bd. XIII., 1877; and R. T. Grant and E. F. Bland, *Heart*, vol. xv. 1929-31.

Some arteries have extremely thin walls in proportion to their size; this is especially the case in those situated within the cranium and vertebral canal, where the external and middle coats of the arteries are reduced in thickness.

The arteries, in their distribution throughout the body, are enclosed in thin fibro-areolar *sheaths*. An artery is loosely connected with its sheath by delicate areolar tissue; and the sheath usually encloses the accompanying veins, and sometimes a nerve.

The larger arteries are supplied with blood-vessels. These nutrient vessels, called the *vasa vasorum*, arise from branches of the artery itself, or of a neighbouring vessel, at some considerable distance from the points at which they are distributed; they ramify in the loose areolar tissue connecting the artery with its sheath, and are distributed to the external coat; in man they do not penetrate the other coats; but in some of the larger mammals a few vessels have been traced into the middle coat. Minute veins return the blood from these vessels; they empty themselves into the vein or veins accompanying the artery. Lymph vessels are also present in the outer coat.

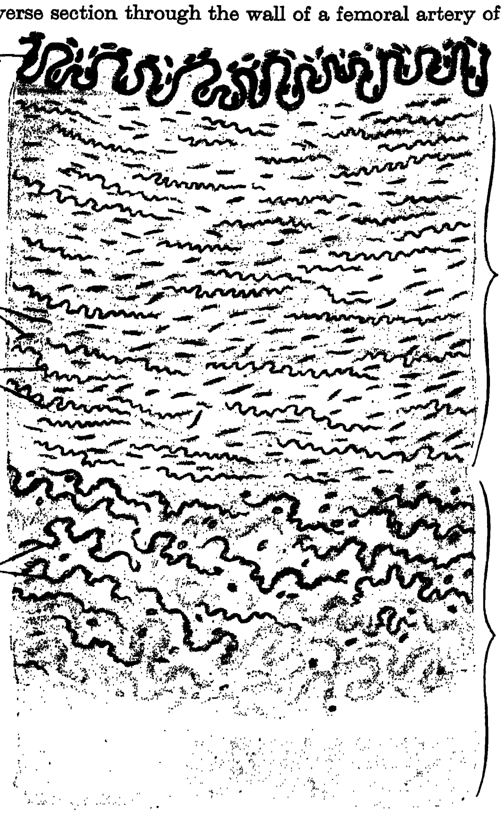
FIG. 667.—A small artery and vein, from the pia mater of a sheep. ×250.



Surface view above the interrupted line; optical section below. Artery in red; vein in blue.

Arteries are also supplied with nerves, which form intricate plexuses upon the surfaces of the larger trunks, and run along the smaller arteries as single filaments, or bundles of filaments. Most of the nerve-fibres are non-medullated, and are derived from the

FIG. 668.—A transverse section through the wall of a femoral artery of a dog. ×250.



sympathetic system, but some are medullated. The non-medullated fibres are mostly efferent, and end in the middle coat. The medullated fibres are believed to be afferent

and are distributed to the outer and inner coats. Lamellated corpuscles (Pacinian corpuscles) are occasionally found in the outer coat of the aorta.

The capillaries.—The arterioles (excepting those of the cavernous structure of the sexual organs, of the splenic pulp, and of the placenta), subdivide into minute vessels named *capillaries* which are interposed between the arterioles and the venules, and constitute a network, the branches of which maintain the same diameter throughout.

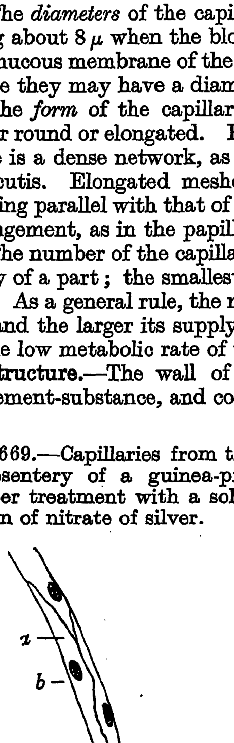
The *diameters* of the capillaries vary in the different tissues of the body, the usual size being about 8 μ when the blood is circulating. The smallest are found in the brain and in the mucous membrane of the intestines; the largest in the skin, and in the marrow of bone, where they may have a diameter of 20 μ.

The *form* of the capillary network varies in the different tissues, the meshes being either round or elongated. Round or angular meshes are most common, and prevail where there is a dense network, as in the lungs, in most glands and mucous membranes, and in the cutis. Elongated meshes occur in muscles and nerves, the long axis of the mesh running parallel with that of the muscle or nerve. Sometimes the capillaries have a looped arrangement, as in the papillæ of the tongue and skin.

The number of the capillaries and the size of the meshes determine the degree of vascularity of a part; the smallest meshes are found in the lungs and in the chorioid coat of the eye. As a general rule, the more active the function of the organ, the closer is its capillary net and the larger its supply of food. Few blood-vessels are present in tendons, because of the low metabolic rate of the tissue of which they are composed.

Structure.—The wall of a capillary consists of flattened cells joined edge to edge by cement-substance, and continuous with the endothelial cells which line the arteries and veins. When stained with nitrate of silver, the material which unites the edges of the epithelial cells is displayed, thus showing the outlines of the cells (fig. 669). These cells are of large size and of an irregular polygonal or lanceolate shape, each containing an oval nucleus, which may be displayed by staining with carmine or hæmatoxylin. Between their edges, at various points of their meeting, rounded, dark spots are sometimes seen, which have been described as stomata, though they are closed by intercellular substance. By some they are believed to be the situations through which the colourless corpuscles of the blood, when migrating from the blood-vessels, emerge; but this view is not universally accepted.

Fig. 669.—Capillaries from the mesentery of a guinea-pig, after treatment with a solution of nitrate of silver.



a. Cells. *b*. Their nuclei.

In developing capillaries, and in the capillaries of the glomeruli of the kidneys, the intestinal villi and the chorioid coat of the eye, intercellular cement cannot be demonstrated, and the cells are believed to form a syncytium.

In many situations a delicate sheath or envelope of branched, nucleated, connective tissue cells is found around the simple capillary tubes, particularly the larger ones; and in other places, especially in the glands, the capillaries are invested with retiform connective tissue.

Rouget (1873) * described a special variety of unstriped muscle cell placed at intervals along certain capillaries. The cells are almost transparent and have long, branching thread-like processes which run round the circumference of the capillary tube and by their contraction cause a local constriction of the vessel (fig. 670). '*Rouget cells*' have been described (*a*) on some capillaries in certain situations in amphibia and (*b*) in some capillaries of the mammal, during certain stages of development. Indisputable evidence has not been adduced to enable one to accept their presence anywhere on a vessel less than about 10 μ in diameter, or on fully formed mammalian capillaries.†

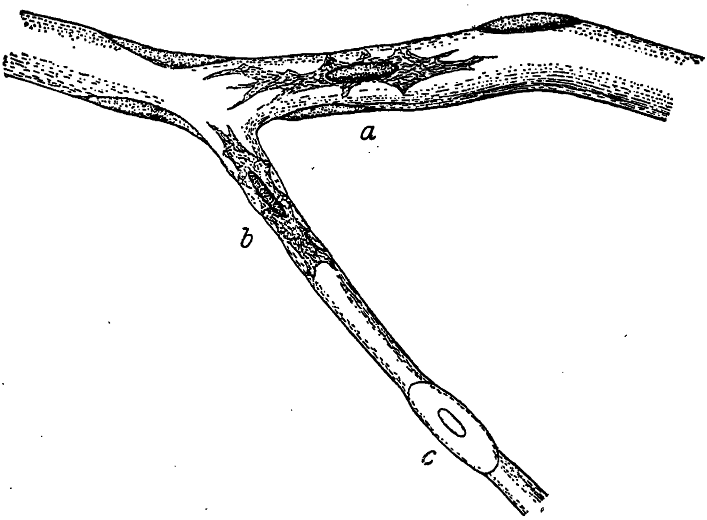
The sinusoids.—In the heart, the liver, the suprarenal and parathyroid glands, and in the carotid and coccygeal bodies, the smallest blood-vessels differ from true capillaries. They are wider, with an irregular lumen, and have no connective tissue covering, their endothelial cells being in direct contact with the cells of the organ. Moreover, their walls are often incomplete. These vessels have been called *sinusoids* by Minot. They are formed by columns of cells or trabeculæ pushing their way into a large blood-vessel or blood-space and carrying its endothelium before them; at the same time the wall of the vessel or space grows out between the columns of cells.

* *A. Physiol. norm. et path.* p. 601.

† Consult *The Anatomy and Physiology of Capillaries*, by August Krogh, 1924.

The veins.—The walls of the veins, like those of the arteries, are composed of three coats—internal, middle, and external; and these are, with the necessary modifications, analogous to the coats of the arteries; the internal being the endothelial, the middle the muscular, and the external the connective tissue or areolar (fig. 666). The main difference between the veins and the arteries is in the comparative weakness of the middle coat in the former.

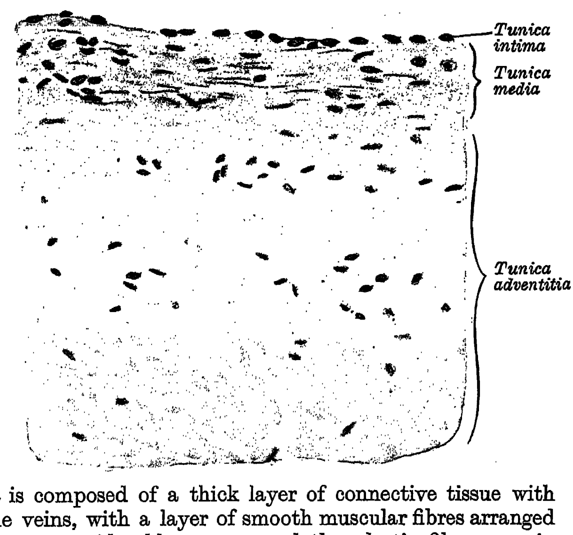
Fig. 670.—Contractile cells of Rouget on the wall of a capillary of the tail of a salamander tadpole (Vimtrup). From *The Endocrine Organs*, by permission of Sir E. Sharpey-Schafer.



a, an expanded cell; *b*, a partially contracted cell which is causing the wall of its capillary to be diminished; *c*, an erythrocyte.

In the smallest veins the three coats are difficult to distinguish (fig. 667). The endothelium is supported on a membrane separable into two layers, the outer of which is the thicker, and consists of a delicate, nucleated membrane (tunica adventitia), while the inner is composed of a network of longitudinal elastic fibres (tunica media). In the veins next above these in size (0·4 mm. in diameter), a connective tissue layer containing numerous smooth muscular fibres circularly disposed forms the middle coat, while the elastic and connective tissue elements of the outer coat are more distinctly perceptible. In the middle-sized veins (fig. 666) the endothelium is of the same character as in the arteries, but its cells are shorter and broader. It is supported by a connective tissue layer, consisting of a delicate network of branched cells, and external to this there is a layer of elastic fibres disposed in the form of a network in place of the definite fenestrated membrane seen in arteries. This constitutes the *tunica intima*. The *tunica media* is composed of a thick layer of connective tissue with elastic fibres, intermixed, in some veins, with a layer of smooth muscular fibres arranged circularly. The white fibres are in considerable excess, and the elastic fibres are in much smaller proportion in the veins than in the arteries. The *tunica adventitia* consists, as in the arteries, of areolar tissue with longitudinal elastic fibres. In the largest veins it is very much thicker than the tunica media, and contains a large number of

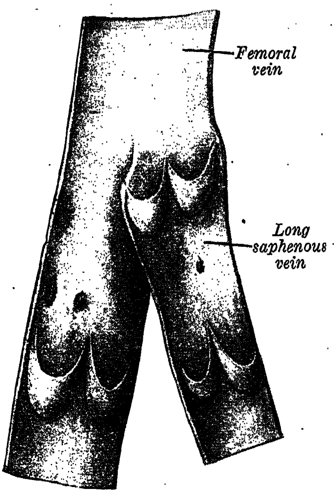
Fig. 671.—A transverse section through the wall of a femoral vein of a dog. ×250. The elastic tissue is not differentiated in this preparation.



longitudinal muscular fibres. These are most distinct in the inferior vena cava, especially at the termination of this vein in the heart, in the trunks of the hepatic veins, in all the large trunks of the portal vein, and in the external iliac, renal and azygos veins. In the inferior vena cava, renal and portal veins they extend through the whole thickness of the outer coat, but in the other veins mentioned a layer of connective and elastic tissue is found external to the muscular fibres. The large veins which open into the heart are covered for a short distance with a layer of cardiac muscle continued on to them from the heart. Muscular tissue is wanting—(1) in the veins of the maternal part of the placenta; (2) in the venous sinuses of the dura mater and the veins of the pia mater; (3) in the veins of the retina; (4) in the veins of the spongy substance of bones; (5) in the venous spaces of the corpora cavernosa and corpus spongiosum. The veins of the above-mentioned parts consist of an endothelial lining supported on areolar tissue.

Most veins are provided with *valves* which serve to prevent the reflux of the blood (fig. 672). Each valve is formed by a reduplication of the inner coat, strengthened by connective tissue and elastic fibres, and is covered on both surfaces by endothelium, the arrangement of which differs on the two surfaces. On the surface of the valve next the wall of the vein, the cells are arranged transversely; while on the other surface, over which the current of blood flows, the cells are arranged longitudinally in the direction of the current. Most commonly two such valves are found placed opposite one another, more especially in the smaller veins or in the larger trunks at the point where they are joined by smaller branches; occasionally there are three, and sometimes only one. The valves are semilunar. They are attached by their convex edges to the wall of the vein; the concave margins are free, directed in the course of the venous current, and lie in close apposition with the wall of the vein as long as the current of blood takes its natural course; if, however, any regurgitation takes place, the valves become distended, their opposed edges are brought into contact, and the current is interrupted. The wall of the vein on the cardiac side of the attachment of each valve is expanded into a pouch or sinus, which gives to the vessel, when injected or distended with blood, a knotted appearance. The valves are very numerous in the veins of the extremities, especially in the veins of the lower extremities, these vessels having to conduct the blood against the force of gravity. They are absent in the very small veins, i.e. those less than 2 mm. in diameter, also in the venæ cavæ, hepatic, renal, uterine and ovarian veins. The cerebral and spinal veins, the veins of the spongy tissue of bone, the pulmonary veins, and the umbilical vein and its branches, are also destitute of valves. A few valves are found in each testicular vein, and one also at its termination. A few valves are occasionally found in the azygos and intercostal veins. Valves are present in the tributaries of the portal vein in the fœtus and for a short time after birth; as a rule they soon atrophy and disappear, but sometimes they persist in a degenerate form.

Fig. 672.—The upper portions of the femoral and long saphenous veins laid open to show valves. About two-thirds of natural size.



The larger veins, like the arteries, are supplied with nutrient vessels, termed *vasa vasorum*. Nerves also are distributed to the veins in the same manner as to the arteries, but in much fewer numbers.

The Thoracic Cavity

The shape and the skeletal walls of the thoracic cavity are described on pp. 238, 239. Its chief contents are the heart and the two lungs.

The inlet of the thorax.—The parts which pass through the upper opening of the thorax are, from before backwards, in or near the median plane, the Sternohyoid and Sternothyroid muscles, the remains of the thymus, the inferior thyroid veins, the trachea, œsophagus, thoracic duct and the Longus cervicis (Longus colli) muscles; laterally the innominate veins, the innominate artery, the left common carotid and left subclavian arteries, the internal mammary arteries and the superior intercostal arteries, the vagus, cardiac, phrenic, and sympathetic nerves, the greater parts of the anterior primary rami of the first

thoracic nerves, and the left recurrent laryngeal nerve. The apices of the lungs, covered by the pleuræ, project through the inlet into the root of the neck.

The **outlet of the thorax** is wider transversely than from before backwards. It slopes obliquely downwards and backwards, so that the thoracic cavity is much longer behind than in front. The Diaphragm (p. 555) closes the opening and forms the convex floor of the thorax. The floor is flatter at the centre than at the periphery, and higher on the right side than on the left; in the dead body the right side of the floor reaches the level of the upper border of the fifth costal cartilage, while the left extends only to the corresponding part of the sixth costal cartilage. From the highest point on each side the floor slopes suddenly downwards to the costal and vertebral attachments of the Diaphragm; this slope is more marked and longer behind than in front, so that only a narrow space is left between the Diaphragm and the posterior wall of the thorax.

The **thoracic cavity**.—The capacity of the thoracic cavity does not correspond with its apparent size, because the lower part of the space enclosed by the ribs is occupied by some of the abdominal viscera. On the other hand, the fact that the thoracic cavity extends for a short distance into the neck above the anterior parts of the first ribs compensates for this difference to a slight extent. During life the size of the thoracic cavity is constantly varying with the movements of the ribs and Diaphragm.

The thoracic cavity is divided into right and left halves by a septum, termed the *mediastinum*, which stretches from the back of the sternum to the vertebral column, and extends from the thoracic inlet above to the Diaphragm below. The heart lies in the mediastinum, enclosed within a fibroserous sac, termed the *pericardium*; the lungs occupy the right and left halves of the thoracic cavity. Each lung is covered with a serous membrane, called the *pleura*, which also lines the wall of the corresponding half of the chest, and forms the lateral boundary of the mediastinum (fig. 682).

For purposes of description the mediastinum is divided into a superior and an inferior part. The *superior part* extends downwards from the thoracic inlet as far as an oblique plane passing through the lower edge of the manubrium sterni in front and the lower border of the fourth thoracic vertebra behind. The *inferior part*, below this plane, is subdivided into three portions, viz. an *anterior* in front of the pericardium, a *posterior* behind the pericardium and Diaphragm, and a *middle*, which contains the pericardium, the heart and the large vessels entering or leaving the latter (fig. 684). Details of the contents of the different parts of the mediastinum are given with the description of the respiratory organs.

The Pericardium

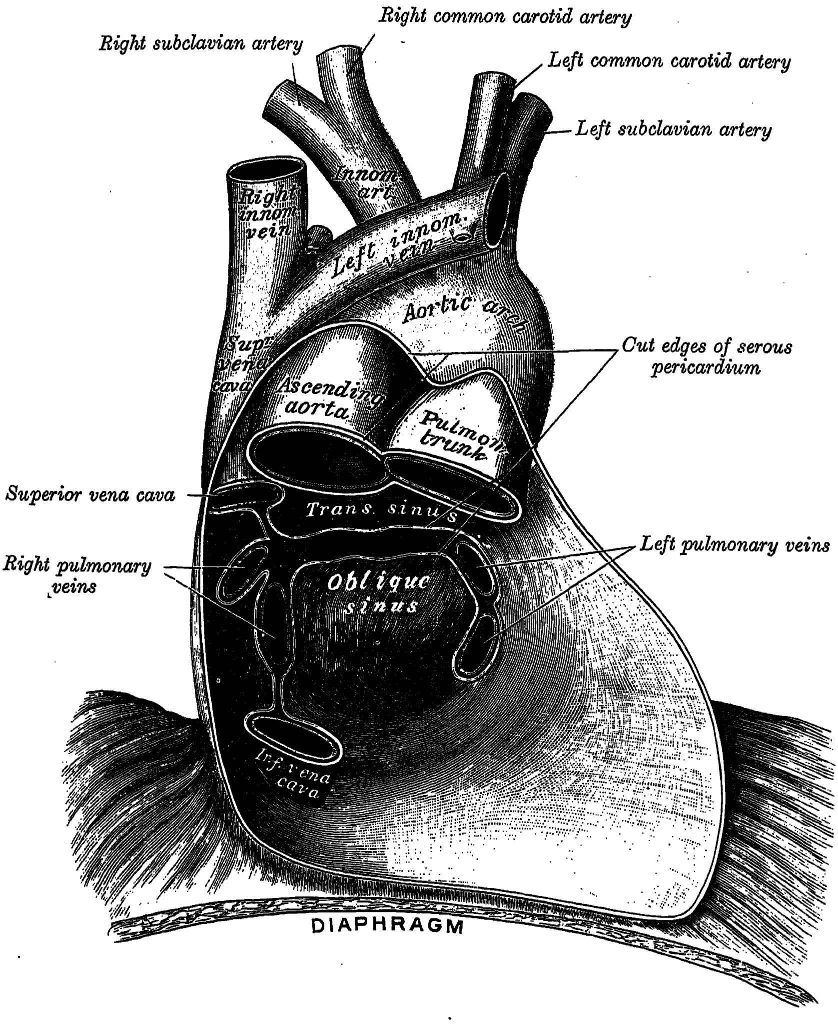
The **pericardium** (fig. 673) is a conical, fibroserous sac, which contains the heart and the roots of the great vessels. It is placed in the mediastinum behind the body of the sternum and the cartilages of the ribs from the second to the sixth inclusive, and in front of the thoracic vertebræ, from the fifth to the eighth inclusive.

The **structure of the pericardium**.—Although the pericardium is usually described as a single sac, an examination of its structure shows that it consists essentially of two sacs intimately connected with one another, but different in structure. The outer sac, known as the *fibrous pericardium*, consists of fibrous tissue. The inner sac, or *serous pericardium*, is a delicate membrane which lines the fibrous sac and covers the heart; it is composed of a single layer of flattened cells resting on loose areolar tissue. The heart invaginates the wall of the serous sac from above and behind, and practically obliterates its cavity, the space being a potential one.

The *fibrous pericardium* is a cone-shaped bag, the apex of which is truncated and continuous with the external coats of the great vessels, while its base is attached to the central tendon and to a small part of the muscular substance of the left half of the Diaphragm. In some of the lower mammals the base is either completely separated from the Diaphragm or joined to it by some loose

fibrous tissue ; in man much of its diaphragmatic attachment consists of loose fibrous tissue which can be readily broken down, but over a small area the central tendon of the Diaphragm and the pericardium are fused. Above, the fibrous pericardium not only blends with the external coats of the great vessels, but is continuous with the pretracheal fascia (p. 538). The fibrous pericardium is also attached to the posterior surface of the sternum by a *superior* and an *inferior sternopericardial ligament* ; the superior passing to the upper end of the body, and the inferior to the lower end. By means of all these connexions it is securely anchored within the thoracic cavity.

FIG. 673.—The posterior wall of the pericardial sac, showing the lines of reflection of the serous pericardium on to the great vessels.



The vessels receiving prolongations from the fibrous pericardium are : the aorta, the superior vena cava, the right and left pulmonary arteries, and the four pulmonary veins. The inferior vena cava, which enters the pericardium through the central tendon of the Diaphragm, receives no covering from the fibrous layer.

The *serous pericardium* is, as already stated, a closed sac which lines the fibrous pericardium and is invaginated by the heart ; it therefore consists of a *visceral* and a *parietal* portion. The visceral portion, or *epicardium*, covers the heart and the great vessels, and from the latter is continuous with the parietal layer, which lines the fibrous pericardium. The portion which covers

the vessels is arranged in the form of two tubes. The aorta and pulmonary trunk are enclosed in one tube ; the superior and inferior venæ cavæ and the four pulmonary veins are enclosed in a second tube, the attachment of which to the parietal layer is ∩-shaped. The cul-de-sac between the limbs of the ∩ lies behind the left atrium and is known as the *oblique sinus*, while the passage between the aorta and pulmonary trunk, in front, and the atria, behind, is named the *transverse sinus* (fig. 673).

Anteriorly, the pericardium is separated from the front wall of the thorax, in the greater part of its extent, by the lungs and pleuræ ; but a small area, usually corresponding with the left half of the lower part of the body of the sternum and the sternal ends of the cartilages of the fourth and fifth ribs of the left side, is in direct relationship with the chest-wall. Until puberty or adolescence the lower end of the thymus is in contact with the front of the upper part of the pericardium. *Posteriorly*, it rests upon the bronchi, the œsophagus, the œsophageal plexus of nerves, the descending thoracic aorta and the posterior part of the mediastinal surface of each lung. *Laterally*, it is covered by the pleuræ, and is in relation with the mediastinal surfaces of the lungs ; the phrenic nerve, with its accompanying vessels, descends between the pericardium and the mediastinal pleura on each side. *Inferiorly*, it is separated from the liver and the fundus of the stomach by the Diaphragm.

The ligament of the left vena cava.—Between the left pulmonary artery and subjacent pulmonary vein is a triangular fold of the serous pericardium, known as the *ligament of the left vena cava.* It is formed by the folding of the serous layer over the remnant of the left duct of Cuvier (left superior vena cava) (p. 158). The lumen of this duct is obliterated during fœtal life, but its wall persists as a fibrous band stretching from the upper part of the left superior intercostal vein to the back of the left atrium, where it is continuous with a small vein, termed the *oblique vein of the left atrium*, which opens into the coronary sinus (fig. 676).

The *arteries* of the pericardium are derived from the internal mammary arteries and their musculophrenic branches, and from the descending thoracic aorta ; its *nerves* are derived from the vagus and phrenic nerves, and the sympathetic trunks.

Applied Anatomy.—Fluid effusions into the pericardial sac may cause serious embarrassment of the heart's action, and paracentesis of the pericardium, and withdrawal of the fluid may be necessary. The puncture may be made in the fifth or sixth left intercostal space near the sternum, with care to avoid wounding the internal mammary artery that usually runs 1·25 cm. lateral to the sternal edge. Alternatively the exploring needle may be entered at the left costoxiphoid angle, and passed upwards and backwards into the pericardial sac. Curschmann recommends paracentesis in or lateral to the left mammary line in the fifth or sixth left interspace, in view of the fact that the fluid tends to collect at the sides of, and below, the heart rather than in front of it.

The Heart (Cor)

The heart is a hollow, muscular organ of a somewhat conical form ; it lies between the lungs in the middle mediastinum (fig. 674), and is enclosed in the pericardium. It is placed obliquely in the chest behind the body of the sternum and adjoining parts of the rib cartilages, and projects farther into the left than into the right half of the thoracic cavity, so that about one-third of it is situated on the right of the median plane and two-thirds on the left (Plate XIII, fig. 1).

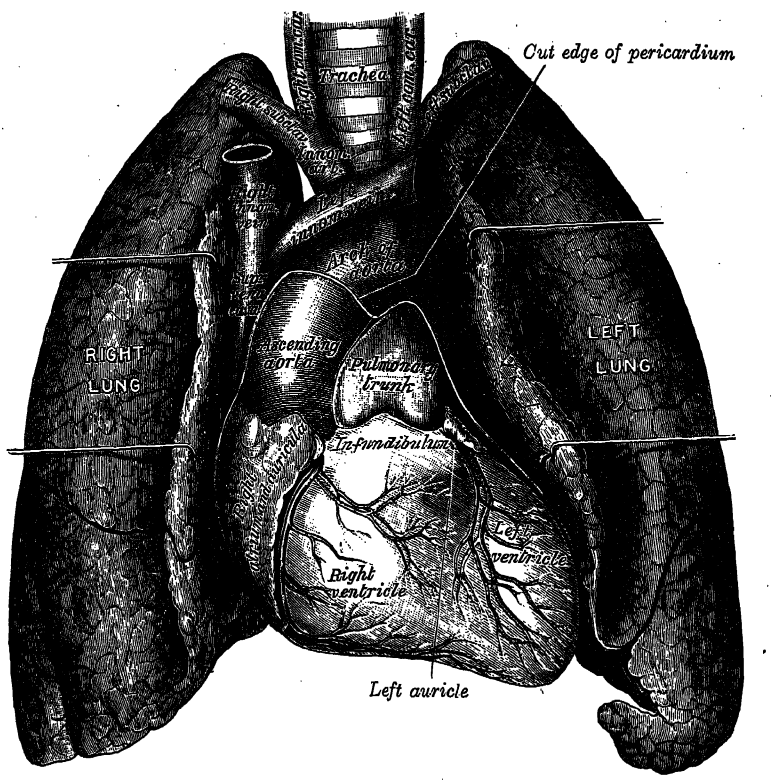
Size.—The heart of the adult measures about 12 cm. from base to apex, 8 to 9 cm. transversely at the broadest part, and 6 cm. anteroposteriorly. Its weight, in the male, varies from 280 to 340 grammes ; in the female, from 230 to 280 grammes. It continues to increase in weight and size up to an advanced period of life, and this increase is more marked in men than in women.

Component parts.—As already stated (p. 661) the heart is divided into four chambers, viz. right and left atria, and right and left ventricles : the division is indicated on the surface of the heart by grooves or sulci. The atria are separated from the ventricles by the *atrioventricular groove* (coronary sulcus) ; this groove contains the trunks of the coronary vessels of the heart, and is

deficient in front, where it is crossed by the root of the pulmonary trunk. The *interatrial groove,* separating the two atria, is scarcely marked on the posterior surface, while anteriorly it is hidden by the pulmonary trunk and aorta. The ventricles are separated by two grooves, termed the *anterior* and *inferior interventricular grooves* (longitudinal sulci); the former is situated on the sternocostal surface of the heart, near its left margin, the latter on the diaphragmatic surface near the right margin; these grooves extend from the base of the ventricular portion to a notch, termed the *incisura apicis cordis,* situated a little to the right of the apex of the heart.

The *base* (fig. 676) is somewhat quadrilateral in form; it faces backwards and to the right, and is separated from the fifth, sixth, seventh and eighth

FIG. 674.—The heart and lungs. Anterior aspect.

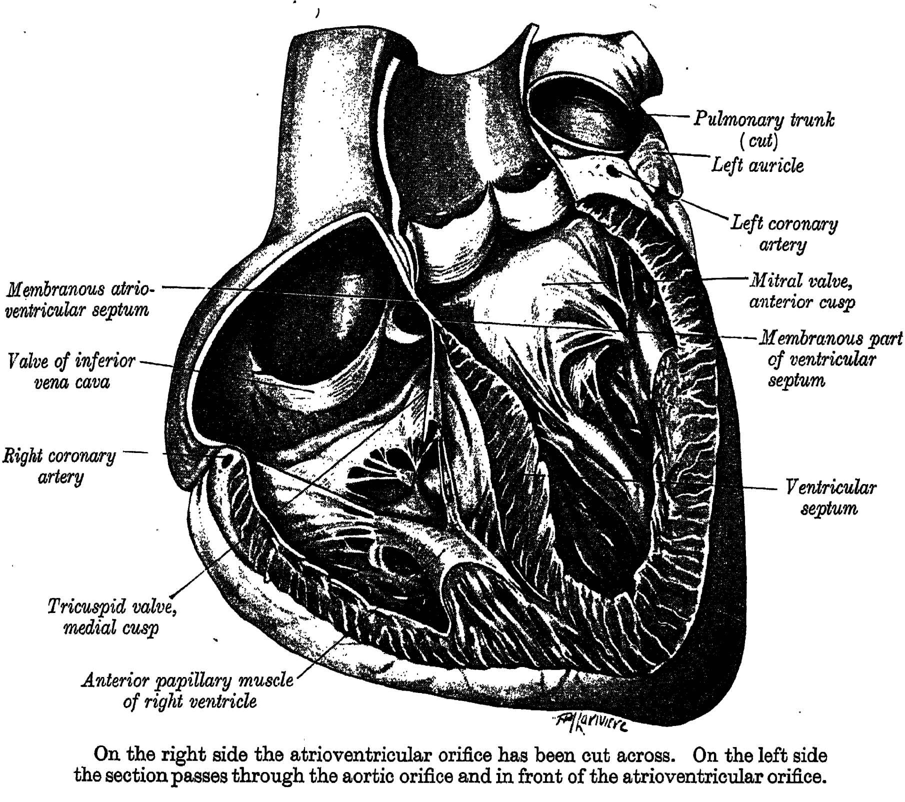


thoracic vertebræ by the pericardium, right pulmonary veins, œsophagus and aorta. It is formed mainly by the left atrium, and, to a small extent, by the posterior part of the right atrium. It is in relation above with the bifurcation of the pulmonary trunk, and is bounded below by the posterior part of the atrioventricular groove, containing the coronary sinus. On the right it is limited by the rounded right border of the right atrium, and on the left by the rounded left border of the left atrium. The four pulmonary veins, two on each side, open into the left atrium, whilst the superior vena cava opens into the upper part, and the inferior vena cava into the lower part, of the right atrium. The portion of the left atrium between the openings of the right and left pulmonary veins constitutes the anterior wall of the oblique sinus of the pericardium (p. 669).

The *apex,* formed by the left ventricle, is directed downwards, forwards and to the left, and is overlapped by the left lung and pleura: it lies behind the left fifth intercostal space, about 8 cm. from the mid-sternal line, or, in the male, about 4 cm. below and 2 cm. to the medial side of the left nipple.

The *sternocostal surface* (fig. 677) is directed forwards, upwards and to the left. It consists of an atrial and a ventricular portion, the former being above and to the right, the latter below and to the left, of the anterior part of the atrioventricular groove. The atrial portion is almost entirely formed by the right atrium ; the greater part of the left atrium is hidden by the ascending aorta and pulmonary trunk (fig. 677), and only a small part of its auricle projects forwards on the left side of the pulmonary trunk. Of the ventricular portion, about one-third is formed by the left, and two-thirds by the right ventricle, the line of separation between the ventricles being marked by the anterior interventricular groove. The sternocostal surface is separated by the pericardium from the body of the sternum, the Sternocostalis (Transversus thoracis) muscles and the cartilages of the third, fourth, fifth and sixth ribs ; owing to

FIG. 675.—A section through the heart, showing the ventricular septum.



On the right side the atrioventricular orifice has been cut across. On the left side the section passes through the aortic orifice and in front of the atrioventricular orifice.

the bulging of the heart towards the left side a much larger part of the surface lies behind the left than the right rib-cartilages. The sternocostal surface is also covered by the pleuræ and the thin, anterior parts of the lungs, with the exception of a small, triangular area corresponding with the cardiac notch in the left lung. The base of this area is represented by a line in the median plane from the level of the fourth costal cartilages to the junction of the body of the sternum with the xiphoid process, and the sides by lines from a point ·4 cm. medial to the apex of the heart to the upper and lower ends of the base line.

The *diaphragmatic surface* (fig. 676), directed downwards and slightly backwards, is formed by the ventricles (chiefly by the left ventricle), and rests upon the central tendon and a small part of the left muscular portion of the Diaphragm. It is separated from the base by the posterior part of the atrioventricular groove, and is traversed obliquely by the inferior interventricular groove.

The *left surface* is directed upwards, backwards and to the left. It is formed almost entirely by the left ventricle, but a small part of the left atrium and the left auricle contribute to its formation superiorly. Convex from before back-

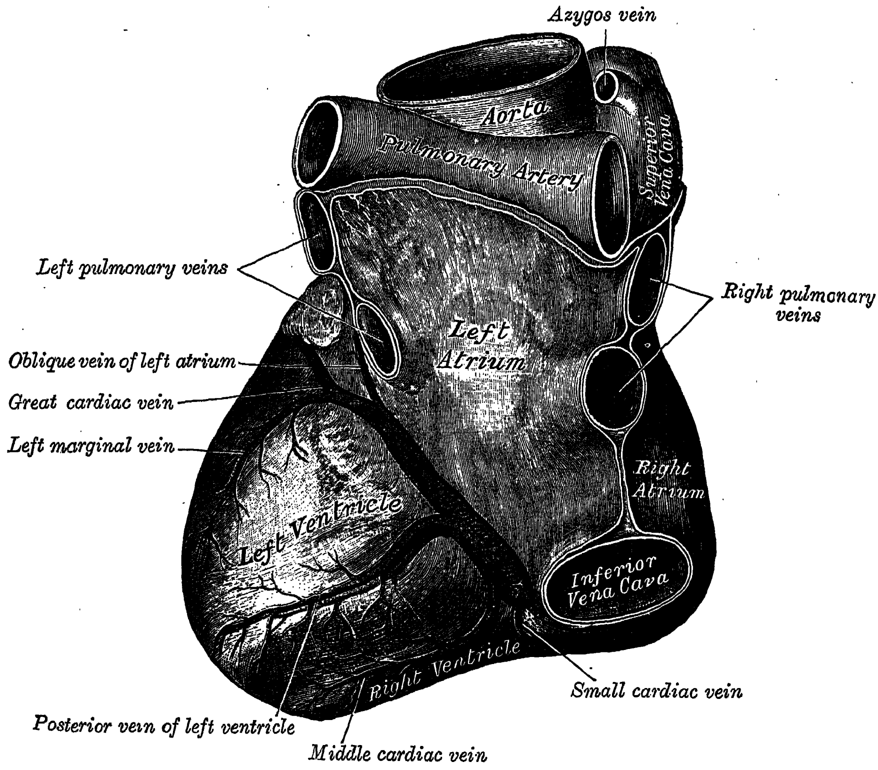
wards and from above downwards, it is widest above, where it is crossed by the atrioventricular groove, and narrowest at the apex. It is separated by the pericardium from the left phrenic nerve and its accompanying vessels, and by the left pleura from the deep hollow on the mediastinal surface of the left lung, below and in front of the hilum.

The *right margin* of the heart, formed by the right atrium, is rounded and almost vertical; it is situated behind the third, fourth and fifth right costal cartilages 1·25 cm. from the margin of the sternum.

The *inferior* or *acute margin*, formed almost entirely by the right ventricle, is nearly horizontal, and extends from the lower limit of the right border to the apex of the heart.

The *left* or *obtuse margin* is rounded, and is formed mainly by the left ventricle, but to a slight extent, above, by the left auricle. It extends from the

Fig. 676.—The base and the diaphragmatic surface of the heart.



left auricle, obliquely downwards, with a convexity to the left, to the apex of the heart, and separates the sternocostal from the left surface.

The **atrial septum**.—A partition, named the *atrial septum* (figs. 678, 682), intervenes between the right and left atria, and is placed so obliquely that the right atrium lies in front and slightly to the right of the left atrium.

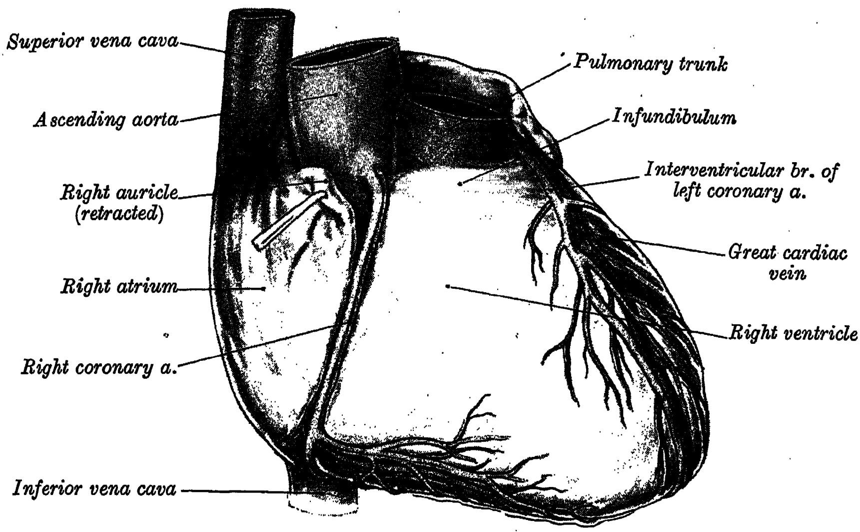
The **right atrium** (figs 677, 678) is a somewhat quadrangular chamber which forms the right surface of the heart. The superior vena cava opens into its upper and posterior part and the inferior vena cava into its lower and posterior part. A small, conical, muscular pouch, termed the *auricle*, projects towards the left from its upper and anterior part and overlaps the right side of the root of the aorta. The margins of the auricle are notched, and its interior is encroached on by an irregular, muscular reticulum.

In well fixed hearts the outer surface of the lateral wall of the atrium is marked by a shallow groove, termed the *sulcus terminalis*, which extends between the right sides of the orifices of the superior and inferior venæ cavæ. It

corresponds in position with the crista terminalis on the inner surface and indicates the line of union of the atrium and the right horn of the sinus venosus, which is incorporated within the right atrium in the adult heart.

Anteriorly, the right atrium is related to the anterior part of the mediastinal surface of the right lung and is separated from it by the pleura and the pericardium. *Laterally*, it is related to the mediastinal surface of the right lung in front of the hilum but is separated from it by the pleura, the right phrenic nerve and pericardiacophrenic vessels and the pericardium. *Posteriorly* and to the left, the right atrium is related to the left atrium and is separated from it by the atrial septum, which forms the posterior wall of the chamber ; posteriorly and to the right, it is related to the right pulmonary veins. *Medially*, it is

FIG. 677.—The sternocostal surface of the heart.



related to the commencement of the ascending aorta and, to a lesser extent, to the root of the pulmonary trunk.

The *interior of the right atrium* (fig. 678) presents the following parts for examination :

Orifices:
- Superior vena cava.
- Inferior vena cava.
- Coronary sinus.
- Foramina venarum minimarum.
- Right atrioventricular.

Valves:
- Valve of the inferior vena cava.
- Valve of the coronary sinus.

Fossa ovalis.
Annulus ovalis.
Intervenous tubercle.
Musculi pectinati.
Crista terminalis.

The *superior vena cava* (figs. 677, 678) returns the blood from the upper half of the body, and opens into the upper and posterior part of the atrium. Its orifice is directed downwards and forwards, and has no valve.

The *inferior vena cava* (fig. 678), larger than the superior, returns the blood from the lower half of the body, and opens into the lowest part of the atrium near the atrial septum ; its orifice is guarded by a rudimentary valve, termed the *valve of the inferior vena cava*.

The *coronary sinus* (fig. 676) returns the greater part of the blood from the substance of the heart. Its opening is placed between the orifice of the inferior

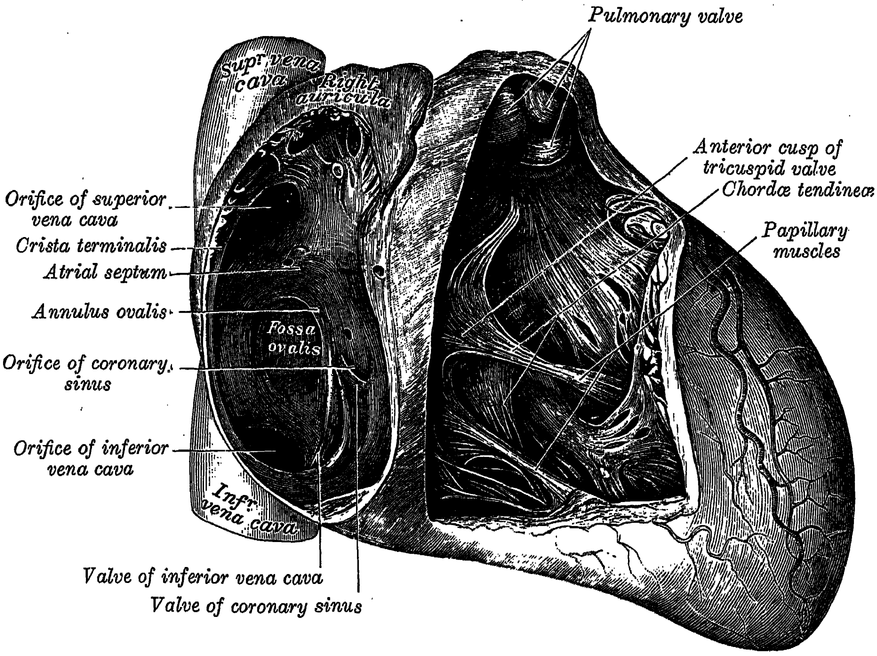
vena cava and the atrioventricular opening, and is protected by a thin, semicircular valve, which is termed the *valve of the coronary sinus.*

The *foramina venarum minimarum* are the orifices of minute veins (*venæ cordis minimæ*), which return a small quantity of blood directly from the substance of the heart. They are more numerous on the septal wall than elsewhere.

The *right atrioventricular orifice* is the large opening between the right atrium and ventricle; it is described with the right ventricle (p. 676).

The *valve of the inferior vena cava* is situated in front of the orifice of the inferior vena cava. It is semilunar in form, its convex margin being attached to the anterior margin of the orifice; its concave margin, which is free, ends in two cornua, of which the left is continuous with the anterior edge of the annulus ovalis (limbus fossæ ovalis), while the right is lost on the wall of

Fig. 678.—The interior of the right side of the heart.



the atrium. The valve is formed by a duplication of the lining membrane of the atrium, enclosing a few muscular fibres. During fœtal life this valve is of large size, and serves to direct the blood from the inferior vena cava into the left atrium, through an opening, named the foramen ovale, in the atrial septum. It varies considerably in size and it sometimes presents a cribriform or filamentous appearance; occasionally it is absent.

The *valve of the coronary sinus* (fig. 678) is a semicircular fold of the lining membrane of the atrium, which covers the lower part of the orifice of the coronary sinus. It prevents the regurgitation of blood into the sinus during the contraction of the atrium. This valve may be double or it may be cribriform.

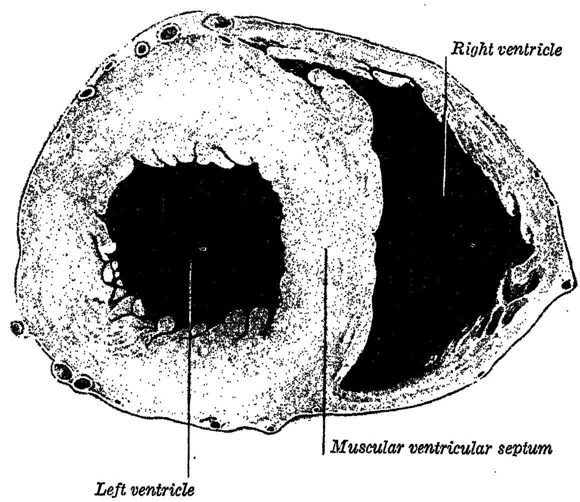
The *fossa ovalis* (fig. 678) is an oval depression on the lower part of the septal wall of the atrium, above and to the left of the orifice of the inferior vena cava. It is formed by the septum primum of the fœtal heart (p. 140).

The *annulus ovalis* (limbus fossæ ovalis) (fig. 678) is the prominent margin of the fossa ovalis. It is most distinct above and at the sides of the fossa; below, it is deficient. Its anterior edge is continuous with the left horn of the valve of the inferior vena cava. A small, slit-like, valvular opening is occa-

sionally found, at the upper margin of the fossa, leading upwards, beneath the limbus, into the left atrium ; it is the remains of the foramen ovale between the two atria.

The *intervenous tubercle* is a small projection on the posterior wall of the atrium, just below the orifice of the superior vena cava. It is distinct in the hearts of quadrupeds, but in man is scarcely visible. During fœtal life it may direct the blood from the superior vena cava towards the right atrioventricular opening.

Fig. 679.—A transverse section through the ventricles of the heart.



The *crista terminalis* is a smooth, muscular ridge, which is placed in the lateral wall of the right atrium and extends from the right side of the orifice of the superior vena cava to the right side of the orifice of the inferior vena cava, where it is connected to the right end of the valve of the latter vessel. It occupies the site of the right venous valve of the embryo (p. 137) and demarcates in the interior of the heart the atrium proper from the smooth-walled *sinus venarum*, into which the great veins open.

The *musculi pectinati* are nearly parallel muscular ridges which run forwards from the crista terminalis across the lateral and anterior walls of the right atrium, inclining towards the atrioventricular orifice. In the auricle they are connected to one another so as to form a muscular network.

The **right ventricle** (figs. 678, 681, 682) extends from the right atrium nearly to the apex of the heart. Its *anterosuperior surface* is convex, and forms a large part of the sternocostal surface of the heart. In the greater part of its extent it is separated from the chest wall only by the pericardium, but the left pleura and, to a lesser extent, the anterior margin of the left lung are interposed both above and to the left side. Its *inferior surface* is flattened and is related to the central tendon and the adjoining part of the Diaphragm, but is separated from it by the pericardium. Its *left*, or *posterior*, *wall* is formed by the ventricular septum, which bulges into the right ventricle, so that a transverse section of the cavity presents a crescentic outline (fig. 679). Its upper left angle forms a conical pouch termed the *infundibulum* (conus arteriosus), from which the pulmonary trunk arises. A tendinous band, which is named the *tendon of the infundibulum*, connects the posterior surface of the infundibulum to the aorta ; this tendon is continuous with the membranous part of the ventricular septum (p. 681). A prominent muscular ridge passes downwards and to the right from the posterior wall of the infundibulum, and intervenes between the atrioventricular and the pulmonary orifices (fig. 681). It is termed the *infundibuloventricular crest*, and it marks the lower limit of the bulbar part of the right ventricle (p. 145). The wall of the right ventricle is thinner than that of the left, the proportion between them being as 1 to 3 ; it is thickest at the base, and gradually becomes thinner towards the apex of the ventricle.

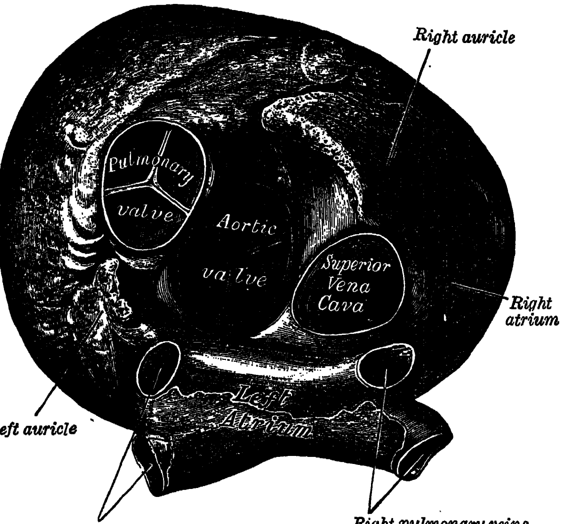
The interior of the right ventricle (fig. 681) presents the following parts for examination :

Orifices { Right atrioventricular. Pulmonary trunk.	Valves { Right atrioventricular or tricuspid. Pulmonary.
Trabeculæ carneæ.	Chordæ tendineæ.

The *right atrioventricular* or *tricuspid orifice* is the large, oval aperture between the right atrium and the right ventricle. Situated at the base of the ventricle, it is encircled by a fibrous ring, covered with the lining membrane of the heart; it is considerably larger than the left atrioventricular orifice, being sufficient to admit the tips of three or four fingers; its circumference measures from 12 to 13 cm. It is guarded by the right atrioventricular (tricuspid) valve.

The *orifice of the pulmonary trunk* is situated at the summit of the infundibulum, close to the ventricular septum; it is circular in form, and has a diameter of about 3 cm. It is placed above and to the left of the atrioventricular opening, and is guarded by the pulmonary valve.

Fig. 680.—The heart. Superior aspect.



The red lines indicate the lines along which the parietal layer of the serous pericardium becomes continuous with the epicardium.

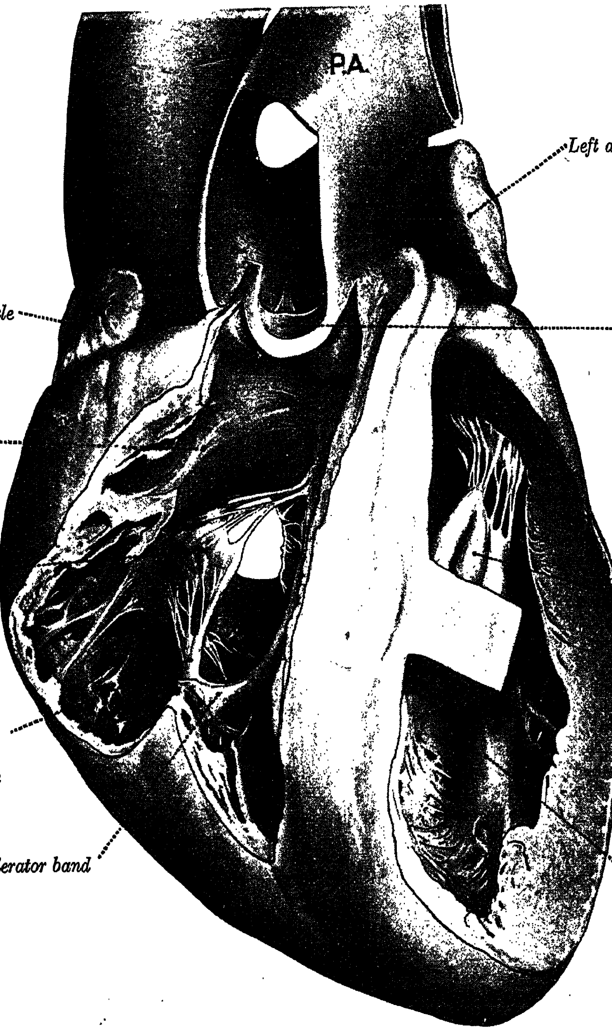
The *right atrioventricular (tricuspid) valve* (figs. 678, 681) guards the right atrioventricular orifice, and consists of three somewhat triangular cusps, named, *anterior*, *inferior* and *medial*; in the angles between the cusps small intermediate segments are sometimes seen. The anterior cusp, the largest, is interposed between the atrioventricular orifice and the infundibulum (conus arteriosus), while the medial cusp is in relation with the ventricular septum. Each cusp is formed by a duplicature of the lining membrane of the heart, strengthened by intervening layers of fibrous tissue. The central parts of the cusps are comparatively thick and strong, their marginal portions thin and translucent. Their bases are attached to the fibrous ring surrounding the atrioventricular orifice and are also joined to each other so as to form a continuous annular membrane, while their apices project into the ventricular cavity. Their atrial surfaces, directed towards the blood-current from the atrium, are smooth; their ventricular surfaces, directed towards the wall of the ventricle, are rough and irregular and, together with the apices and margins of the cusps, give attachment to a number of delicate, tendinous cords, which are termed the *chordæ tendineæ*.

The *trabeculæ carneæ* are round or irregular muscular columns which project from the whole of the inner surface of the ventricle, with the exception of the infundibulum (conus arteriosus), the wall of which is smooth. They are of three kinds: some are mere ridges, others are fixed at their ends but free in the middle, while a third set (*musculi papillares*) are continuous by their bases with the wall of the ventricle, while their apices project into the cavity, and give origin to the chordæ tendineæ, which pass to be attached to the segments of the tricuspid valve. There are two papillary muscles, anterior and inferior (posterior); the anterior is the larger, and its chordæ tendineæ are connected with the anterior and inferior cusps of the valve; the inferior papillary muscle sometimes consists of two or three parts, and its chordæ tendineæ are connected with the inferior and medial cusps. Some chordæ tendineæ also spring directly from the ventricular septum, or from small septal papillary muscles, and pass to the anterior and medial cusps. A muscular band, well-marked in sheep and some other animals, frequently extends from the ventricular septum to the base of the anterior papillary muscle and serves to convey the right fasciculus of the atrioventricular bundle (p. 684). From its attachments it may assist

in preventing over-distension of the ventricle, and so has been named the *moderator band* (fig. 681).

The *pulmonary valve* (figs. 678, 680) consists of three semilunar segments or cusps, which are attached, by their convex margins, to the wall of the pulmonary trunk at its junction with the ventricle, their free borders being directed

FIG. 681.—A dissection of the ventricles, viewed from in front. (A. K. Maxwell.) From Quain's *Elements of Anatomy*, 11th edition, vol. iv., part iii. *The Heart*, by Professor Thomas Walmsley, 1929.



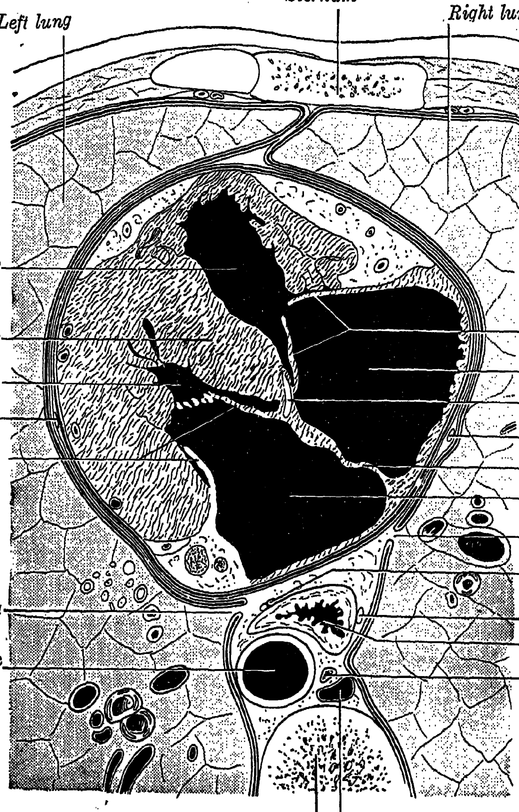
upwards into the lumen of the vessel. Two of the cusps are situated anteriorly (right and left) and the third is posterior. Each consists of a duplicature of the lining membrane, with a little fibrous tissue interposed between the two endothelial layers. The free and attached margins are strengthened by tendinous fibres, and at the middle of the free margin there is a thickened *nodule*. From this nodule tendinous fibres radiate through the cusp to its attached margin, but are absent from two narrow crescentic portions, which are termed the *lunulæ*. These are placed one on each side of the nodule, and immediately adjoining the free margin. Opposite to the semilunar cusps the pulmonary trunk presents three slight dilatations or sinuses.

The left atrium is rather smaller than the right, but its walls are thicker,

measuring about 3 mm. A small somewhat conical pouch, termed the *auricle*, projects forwards from its upper left corner.

The cavity of the left atrium is formed to a large extent by the proximal parts of the pulmonary veins, which are incorporated during its development (p. 141). It is cuboidal in form, and extends to the right behind the right atrium, from which it is separated by the atrial septum. Anteriorly, and to the left, it is concealed by the roots of the pulmonary trunk and aorta. Its posterior aspect forms most of the base of the heart (p. 670) and lies in the

FIG. 682.—A transverse section through the mediastinum at the level of the body of the seventh thoracic vertebra.



anterior wall of the oblique sinus of the pericardium. The two pulmonary veins open into it on each side.

The *auricle* is somewhat constricted at its junction with the principal cavity; it is longer, narrower and more curved than that of the right atrium, and its margins are more deeply indented. It is directed forwards on the left side of the pulmonary trunk, and overlaps the root of this vessel.

The interior of the left atrium (fig. 685) presents the following parts for examination:

Orifices of the four pulmonary veins.
Left atrioventricular orifice.
Foramina venarum minimarum.
Musculi pectinati.

The *pulmonary veins*, four in number, open into the upper part of the posterior surface of the left atrium—two on each side of its middle line; their

orifices are not provided with valves. The two left veins frequently end by a common opening.

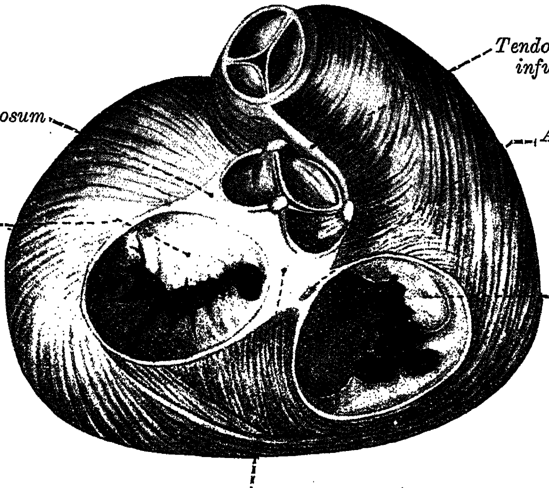
The *left atrioventricular orifice* is the aperture between the left atrium and ventricle ; it is described below.

The *foramina venarum minimarum* are the orifices of minute veins (venæ cordis minimæ) which return a small quantity of blood from the muscular substance of the heart.

The *musculi pectinati*, fewer and smaller than those in the right atrium, are confined to the inner surface of the auricle.

On the atrial septum a lunate impression may be seen, bounded below by a crescentic ridge, the concavity of which is directed upwards. The depression is just above the fossa ovalis of the right atrium.

FIG. 683.—The base of the ventricles, after removal of the atria and the pericardium. From Quain's *Elements of Anatomy*, vol. iv., part iii. *The Heart*, by Professor Thomas Walmsley, 1929.



The **left ventricle** is longer and more conical in shape than the right, and on transverse section its cavity presents an oval or nearly circular outline (fig. 679). It takes part in the formation of the sternocostal and left surfaces of the heart and is related to the mediastinal surface of the left lung, but the pericardium, the left phrenic nerve and pericardiacophrenic vessels, and the left pleura intervene between them. Inferiorly, it forms a large part of the diaphragmatic surface of the heart, and, anteriorly, it is separated from the right ventricle by the ventricular septum. It also forms the apex of the heart. Its walls are about three times as thick as those of the right ventricle.

Its interior (figs. 681, 685) presents the following parts for examination :

Orifices { Left atrioventricular. Aortic — Valves { Left atrioventricular or mitral. Aortic.

Trabeculæ carneæ. — Chordæ tendineæ.

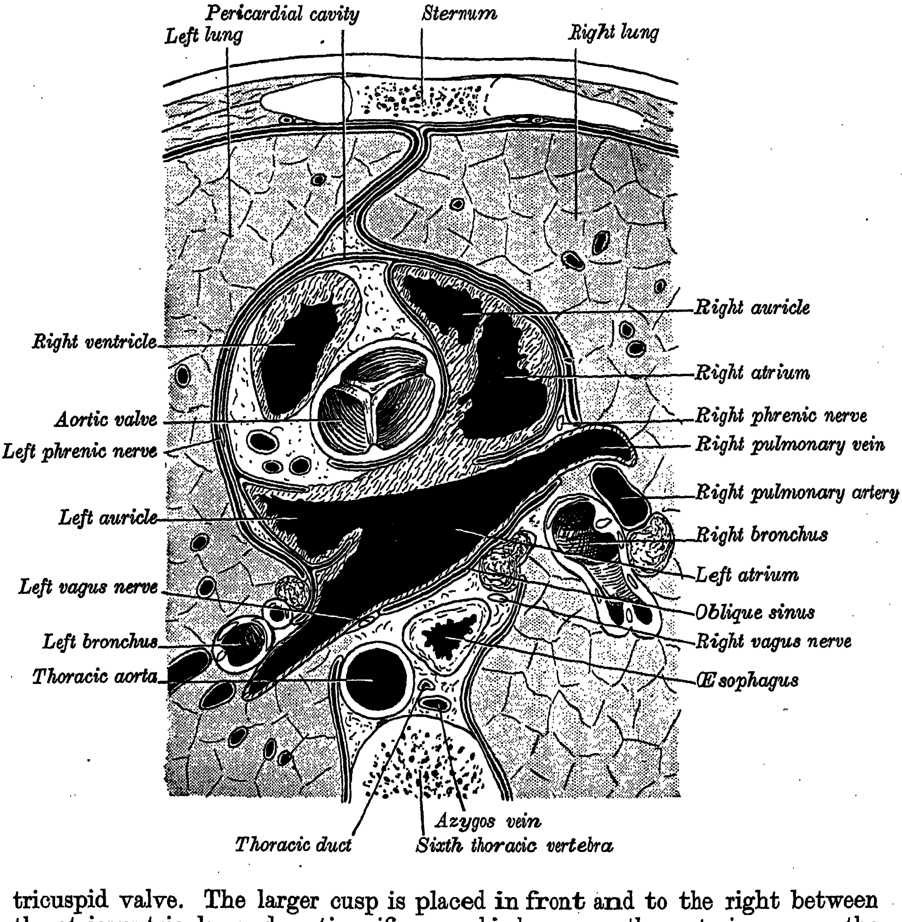
The *left atrioventricular* or *mitral orifice* is placed below and to the left of the aortic orifice. It is smaller than the right atrioventricular orifice, admitting the tips of two or three fingers ; its circumference measures a little over 10 cm. It is surrounded by a dense, fibrous ring and is guarded by the left atrioventricular or mitral valve.

The *aortic orifice* is a circular aperture in front and to the right of the left atrioventricular orifice, from which it is separated by the anterior cusp of the mitral valve. Its orifice has a diameter of a little over 2·5 cm., and is guarded by the aortic valve. The portion of the ventricle immediately below the aortic

orifice is termed the *aortic vestibule,* and possesses fibrous instead of muscular walls.

The *left atrioventricular* or *mitral valve* (figs. 683, 685) is attached to the fibrous ring which encircles the left atrioventricular orifice in the same way as the tricuspid valve is attached around the right atrioventricular orifice. It consists of two triangular cusps, formed by duplications of the lining membrane, strengthened by fibrous tissue and containing a few muscular fibres. The cusps are of unequal size, and are larger, thicker and stronger than those of the

FIG. 684.—A transverse section through the mediastinum at the level of the lower part of the body of the sixth thoracic vertebra.



tricuspid valve. The larger cusp is placed in front and to the right between the atrioventricular and aortic orifices, and is known as the *anterior cusp* ; the smaller or *posterior cusp* is placed behind and to the left of the opening. Two small cusps are usually found in the angles between the larger cusps. The cusps of the mitral valve are furnished with chordæ tendineæ, which are attached in a manner similar to those on the right side of the heart ; they are, however, thicker, stronger and less numerous.

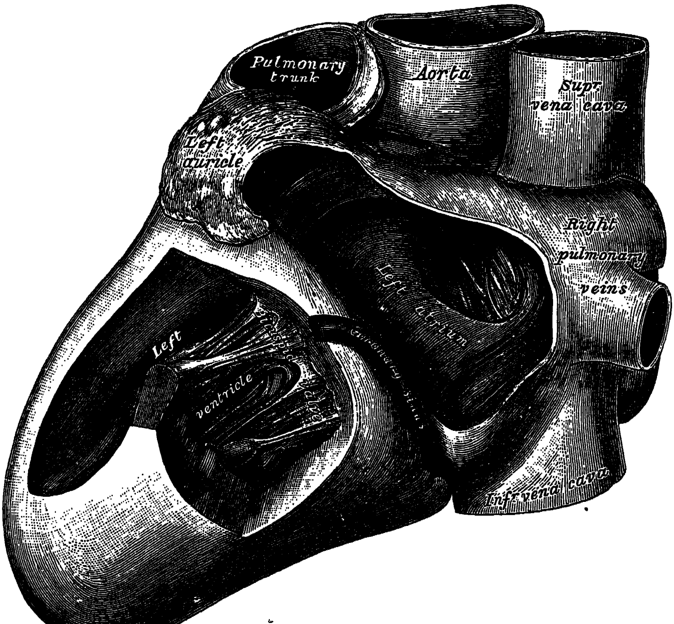
The *aortic valve* (figs. 680, 686) consists of three semilunar segments or cusps which surround the orifice of the aorta ; two are posterior (right and left), and one anterior. They are similar in structure, and in their mode of attachment, to the cusps of the pulmonary valve, but are larger, thicker and stronger ; the lunulæ are more distinct, and the nodules thicker and more prominent (fig. 686). Opposite the cusps the aorta presents three slight dilatations, termed the *aortic sinuses,* which are larger than those at the origin of the pulmonary trunk.

The *trabeculæ carneæ* are of three kinds, like those in the right ventricle, but they are more numerous, and present a dense interlacement, especially at the

apex and upon the posterior wall of the ventricle. The *papillary muscles* are two in number, one [superior] springing from the sternocostal, the other [inferior] from the diaphragmatic wall ; they are of large size, and end in rounded extremities, from which the chordæ tendineæ arise. Chordæ tendineæ from each papillary muscle are attached to both cusps of the mitral valve.

The **ventricular septum.**—The right ventricle is separated from the left by the *ventricular septum* (figs. 675, 690), which slopes obliquely from before backwards and towards the right, and is curved with the convexity towards the right ventricle (fig. 679) : its margins correspond with the anterior and inferior interventricular grooves on the surface of the heart. The greater portion of the septum is thick and muscular ; in its upper part, just below the junction of the anterior and right cusps of the aortic valve, there is a thin, fibrous area,

FIG. 685.—The interior of the left side of the heart.



which is termed the *membranous part of the ventricular septum* (fig. 690). This part of the septum is small in extent and oval in outline. On its right side it is crossed near its centre by the upper part of the attached border of the medial (septal) cusp of the tricuspid valve, which divides it into anterior and posterior portions. The anterior part separates the two ventricles from each other and may occasionally be congenitally defective (p. 146) ; the posterior part (atrioventricular septum) intervenes between the aortic vestibule of the left ventricle and the right atrium near the anterior horn of the annulus ovalis (limbus fossæ ovalis) (p. 146). Superiorly, the membranous part of the ventricular septum can be traced into the tendon of the infundibulum (conus arteriosus).

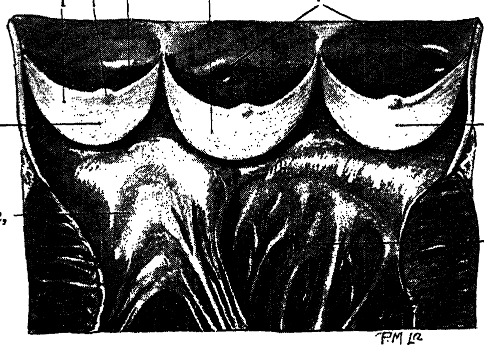
Structure.—The heart consists of muscular fibres (*myocardium*), and of fibrous rings which serve partly for their attachment. It is covered with the visceral layer of the serous pericardium (*epicardium*), and lined with the *endocardium*.

The *endocardium* is a thin, smooth, glistening membrane which lines the chambers of the heart, and is continuous with the lining membrane of the large blood-vessels ; by its reduplications it assists in forming the valves. It consists of a layer of endothelial cells placed on a stratum of connective tissue and elastic fibres.

The *fibrous rings* surround the atrioventricular and arterial orifices, and are stronger on the left than on the right side of the heart. The atrioventricular

rings serve for the attachment of the muscular fibres of the atria and ventricles, and for the attachment of the atrioventricular valves. The interval between the aortic arterial ring, in front, and the atrioventricular rings, behind (fig. 683), is occupied by a tough mass of fibrous tissue, which represents the *os cordis* of some of the larger mammals and is termed the *trigonum fibrosum dextrum.* A similar, but smaller, mass of fibrous tissue, termed the *trigonum fibrosum*

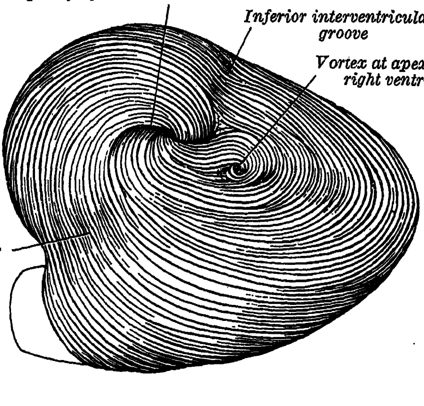
FIG. 686.—The aortic orifice laid open to show the aortic valve.



sinistrum, lies between the left side of the aortic arterial ring and the front of the left atrioventricular ring. The tendon of the infundibulum (conus arteriosus) has already been mentioned (p. 675).

The fibrous rings surrounding the arterial orifices serve for the attachment of the great vessels and their valves. Each ring receives, by its ventricular margin, the attachment of some of the muscular fibres of the ventricles; its opposite margin presents three deep, semicircular notches, to which the middle coat of the artery is firmly fixed. The attachment of an artery to its fibrous ring is strengthened by the external coat of the artery and the epicardium externally, and by the endocardium internally. From the margins of the semicircular notches the fibrous structure of the ring is continued into the segments of the valves. The middle coat of the artery in this situation is thin, and the vessel is dilated to form the sinuses of the aorta and pulmonary trunk.

FIG. 687.—The two vortices at the apex of the heart. (Mall.)



The *muscular structure of the heart* consists of fibres which are transversely and longitudinally striated (p. 35), and present an exceedingly intricate interlacement. They comprise (*a*) the fibres of the atria, (*b*) the fibres of the ventricles and (*c*) the atrioventricular bundle.

The *fibres of the atria* are arranged in two layers—a superficial, common to both atria, and a deep, proper to each. The *superficial fibres* are most distinct on the front of the atria, across the bases of which they run in a transverse direction, forming a thin and incomplete layer; some of them pass into the atrial septum. The *deep fibres* consist of looped and annular fibres. The *looped fibres* pass upwards over each atrium, and are attached by their extremities to the corresponding atrioventricular ring, in front and behind; the *annular fibres* surround the auricles, and form annular bands around the terminations of the veins and around the fossa ovalis.

The *fibres of the ventricles* are arranged in a complex manner, and various accounts have been given of their course and connexions; the following description is based on that given by MacCallum.* They consist of superficial and deep layers, all of which, with the exception of two, are inserted into the papillary muscles of the ventricles. The *superficial layers* comprise the following: (*a*) Fibres which spring from the tendon of the infundibulum (p. 675) and sweep downwards and towards the left across the anterior interventricular groove and around the apex of the heart, where they form a vortex (fig. 687) and pass upwards and inwards to terminate in the papillary muscles of the left ventricle; those arising from the upper (anterior) half of the tendon of the infundibulum pass to the inferior and septal papillary muscles, those from the lower (posterior) half to the superior papillary muscle. (*b*) Fibres which arise from the right atrioventricular ring and run diagonally across the diaphragmatic surface of the right ventricle and round its right border on to its sternocostal surface. There they dip beneath the fibres just described, and, crossing the anterior interventricular groove, wind around the apex of the heart and end in the inferior papillary muscle of the left ventricle. (*c*) Fibres which spring from the left atrioventricular ring, and, crossing the inferior interventricular groove, pass successively into the right ventricle and end in its papillary muscles. The *deep layers* are three in number; they arise in the papillary muscles of one ventricle and, curving in an S-shaped manner, turn in at the interventricular groove and end in the papillary muscles of the other ventricle (fig. 689). The layer which is most superficial in the right ventricle lies next the lumen of the left, and vice versa. Those of the first layer almost encircle the right ventricle and, crossing in the septum to the left ventricle, unite with the superficial fibres from the right atrioventricular ring to form the inferior papillary muscle. Those of the second layer have a less extensive course in the wall of the right ventricle and a correspondingly greater course in the left, where they join with the superficial fibres from the upper half of the tendon of the infundibulum (conus arteriosus) to form the papillary muscles of the septum. Those of the third layer pass almost entirely round the left ventricle and unite with the superficial fibres from the lower half of the tendon of the infundibulum (conus arteriosus) to form the superior papillary muscle. The arrangement of these three layers ensures the synchronisation of ventricular systole and the closure of the atrioventricular valves. Besides the layers just described there are two bands which do not end in papillary muscles. One springs from the right atrioventricular ring, crosses in the atrioventricular septum, encircles the deep layers of the left ventricle and ends in the left atrioventricular ring. The second band is apparently confined to the left ventricle; it is attached to the left atrioventricular ring and encircles the portion of the ventricle adjacent to the aortic orifice.†

FIG. 688.—A diagram of the superficial muscular fibres of the ventricles of the heart originating in the tendon of the infundibulum. (After MacCallum.)

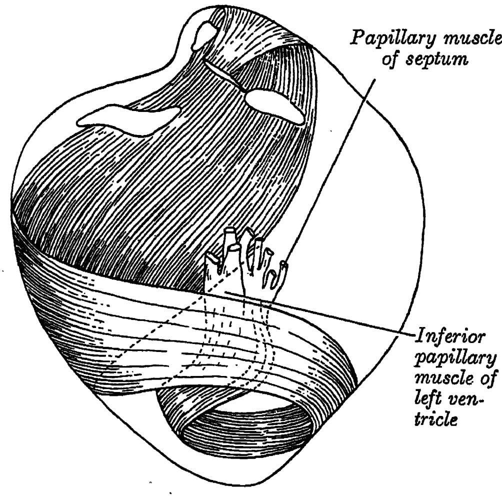
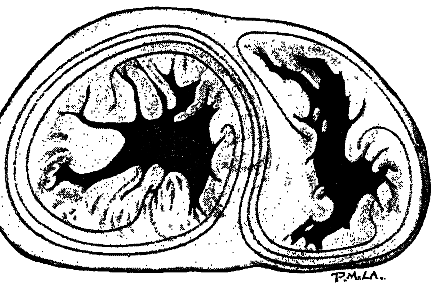


FIG. 689.—A diagram of the arrangement of the deep layers of the muscular fibres of the ventricles, as seen in a cross-section of the ventricles. (Based on MacCallum's description.)



A. Blackhall-Morison ‡ draws attention to the existence of a set of fibres belonging to the left ventricular musculature and to the lower segment of the left atrium, and which

* John Bruce MacCallum, *Johns Hopkins Hospital Reports*, vol. ix.

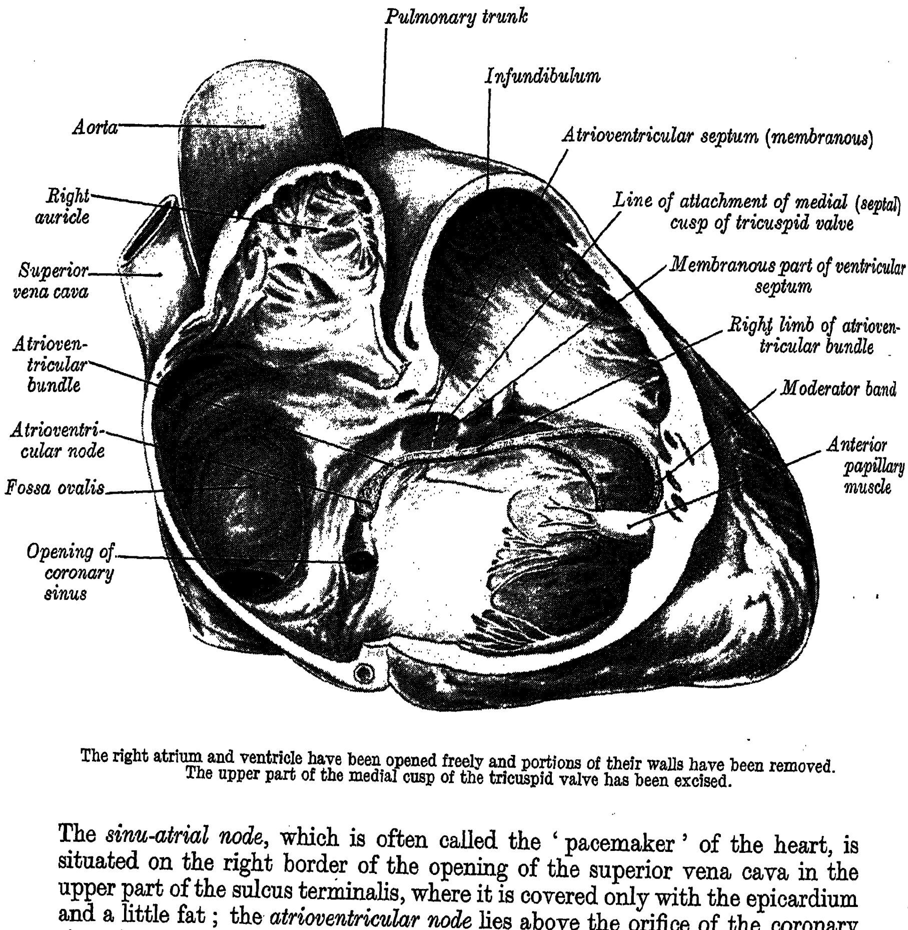
† Franklin P. Mall gives an account of his researches "On the Muscular Architecture of the Ventricles of the Human Heart" in the *American Journal of Anatomy*, vols. 11 and 13.

‡ *Edinburgh Medical Journal*, New Series, vol. xxx. No. 9, September 1923.

have a triple insertion into the base of the aorta, close to the cusps of the aortic valve. The effect of the contraction of these fibres " is to rotate the base of the aorta in the direction of the general ventricular twist in systole."

The *atrioventricular bundle* (fig. 690) is a direct, muscular connexion between the atria and the ventricles. It arises in association with two branching networks of fine, striated muscle fibres, which differ from the cardiac muscle fibres in several features and are termed the sinu-atrial and atrioventricular nodes.

FIG. 690.—A schematic representation of the atrioventricular bundle. The course of the bundle is represented in red.



The right atrium and ventricle have been opened freely and portions of their walls have been removed. The upper part of the medial cusp of the tricuspid valve has been excised.

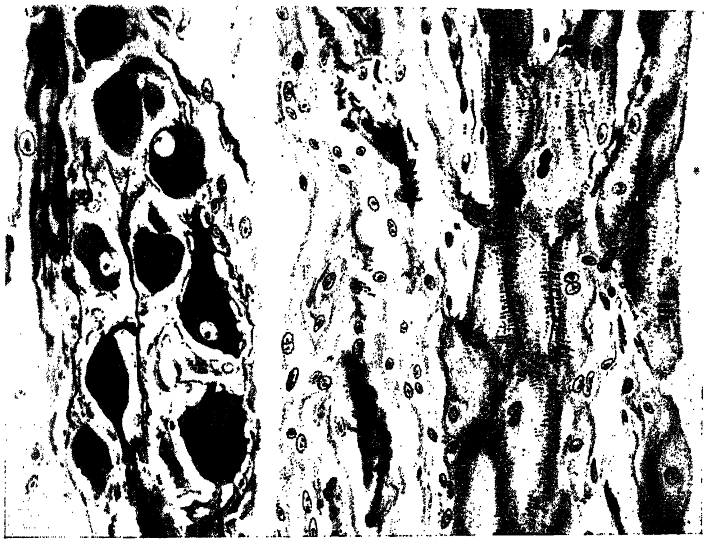
The *sinu-atrial node*, which is often called the 'pacemaker' of the heart, is situated on the right border of the opening of the superior vena cava in the upper part of the sulcus terminalis, where it is covered only with the epicardium and a little fat; the *atrioventricular node* lies above the orifice of the coronary sinus in the annular and septal fibres of the right atrium. From the atrioventricular node the atrioventricular bundle passes upwards in the trigonum fibrosum dextrum until it reaches the posterior margin of the membranous part of the ventricular septum, and then turns forwards below it. In this situation it divides into right and left fasciculi which straddle the muscular septum. These run down in the right and left ventricles, one on each side of the ventricular septum, covered with endocardium. The right fasciculus passes into the moderator band, and breaks up into numerous strands, which end in an intricate network on the papillary muscles and on the wall of the right ventricle. The left fasciculus consists of two main strands, an anterior and a posterior, which are distributed to the papillary muscles and the wall of the left ventricle. In the ox the atrioventricular bundle and its divisions are enveloped in a sheath of connective tissue; by injecting this sheath with Indian ink the ramifications of the bundle can be demonstrated. In the human heart the sheath is not well developed; it surrounds the bundle but not the fasciculi. The nodes and greater portion of the bundle consist of narrow, somewhat

fusiform fibres, but the terminal strands of the bundle are composed of modified Purkinje's fibres (fig. 691). No direct connexion between the two nodes has been proved to exist.

Kent has described a second atrioventricular bundle in the right lateral wall of the heart, containing cardiac muscle-fibres, fine nerve-fibres, and fibres resembling those of Purkinje.

A. Blackhall-Morison * has shown that in the sheep and pig the atrioventricular bundle " is a great avenue for the transmission of nerves from the auricular to the ventricular heart " ; large and numerous nerve-trunks enter the bundle and course with it. Branches

FIG. 691.—Longitudinal section of the left fasciculus of the atrioventricular bundle from the heart of a cow. ×260. Note the incomplete striation of the cells of the fasciculus. Drawn from a microphotograph kindly lent by Professor D. M. Blair and Dr. Francis Davies.



arise from these nerve-trunks and form plexuses around groups of Purkinje cells, and from these plexuses fine fibrils go to innervate individual cells.

The sinu-atrial and atrioventricular nodes, the atrioventricular bundle and its right fasciculus, are supplied by the right coronary artery ; the left fasciculus of the bundle is supplied by both coronary arteries.

Applied Anatomy.—Clinical and experimental evidence goes to prove that this bundle conveys impulses from the atrial septum to the ventricles, and much attention has been paid to it, because it may become fibrosed and lose much of its conducting power (heart-block). The condition is characterised by a slow pulse, a tendency to syncopal or epileptiform seizures, and the fact that while the cardiac atria beat at a normal rate, the ventricles contract much less frequently.

Vessels and Nerves.—The *arteries* supplying the heart are the right and left coronary branches of the aorta (p. 693) ; the majority of the *veins* are drained by the coronary sinus into the right atrium.

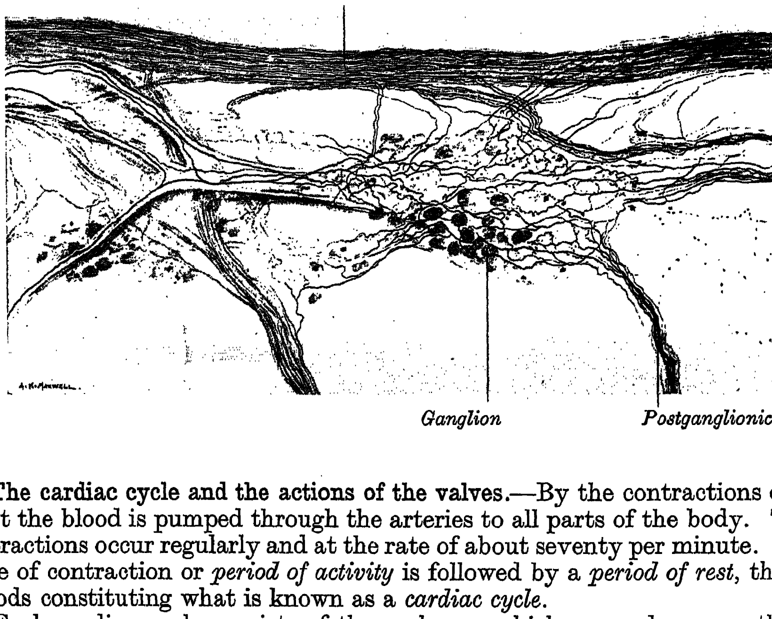
The *lymph vessels* are described on p. 878.

The *nerves* are derived from the cardiac plexus (p. 1149), which is formed by branches from the vagi and sympathetic. They are freely distributed both on the surface and in the substance of the heart, the separate nerve-filaments being furnished with small ganglia. The atrioventricular bundle receives nerve-fibres from ganglia in the atrial septum. Other ganglia are found in relation with the sinu-atrial node, and supply it with nerve-filaments.

* *Journal of Anatomy and Physiology*, vol. xlvi.

H. H. Woollard (*Journal of Anatomy*, vol. lx. 1926) has investigated, by the methylene blue method, the distribution of the cardiac nerves in the dog, cat, rabbit and guinea-pig. His chief conclusions are: 1. In the intracardiac ganglia the types of cell, though varying in the disposition of the dendrites and in the mode of the ending of the preganglionic fibres, all belong to the parasympathetic (fig. 692). 2. There is some evidence to show that the atria and the atrioventricular bundle are supplied by parasympathetic and sympathetic fibres, while the ventricular muscle is supplied by sympathetic fibres only. 3. The fibres spin a plexus about the muscle-cell, and ultimately enter the protoplasm of the muscle and run in the protoplasmic connexions of the muscle; small endings, often perinuclear in position, are given off inside the muscle-cell. 4. The valves, the subendocardial and the subepicardial tissues are innervated by a very fine plexus of nerves which, for the most part, belongs to the sympathetic system. 5. The larger branches of the coronary arteries are predominantly innervated by sympathetic, the finer branches by parasympathetic, fibres.

FIG. 692.—Nerves and ganglia from the posterior surface of the left atrium of a dog. Methylene blue preparation. ×55. H. H. Woollard.



The cardiac cycle and the actions of the valves.—By the contractions of the heart the blood is pumped through the arteries to all parts of the body. These contractions occur regularly and at the rate of about seventy per minute. Each wave of contraction or *period of activity* is followed by a *period of rest*, the two periods constituting what is known as a *cardiac cycle*.

Each cardiac cycle consists of three phases, which succeed one another as follows: (1) a short, simultaneous contraction of both atria, termed the *atrial systole*, followed, after a slight pause, by (2) a simultaneous, but more prolonged, contraction of both ventricles, named the *ventricular systole*, and (3) a *period of rest*, or *diastole*, during which the whole heart is relaxed. The atrial contraction commences at the sinu-atrial node, and sweeping over the atria forces their contents through the atrioventricular openings into the ventricles, regurgitation into the veins being prevented by the contraction of their muscular coats. When the ventricles contract, the atrioventricular valves are closed, and prevent the passage of the blood back into the atria; the papillary muscles at the same time are shortened, and, pulling on the chordæ tendineæ, prevent the inversion of the valves into the atria. As soon as the pressure in the ventricles exceeds that in the pulmonary trunk and aorta, the valves guarding the orifices of these vessels are opened, and the blood is driven from the right ventricle into the pulmonary trunk, and from the left ventricle into the aorta. The moment the systole of the ventricles ceases, the pressure of the blood in the pulmonary trunk and aorta closes the pulmonary and aortic valves, thus preventing regurgitation of blood into the ventricles, and the valves remain shut until re-opened by the next ventricular systole. During the period of rest the tension of the atrioventricular valves is relaxed, and blood flows from the veins through the atria into the ventricles. The filling of the ventricles is

completed by the systole of the atria. The average duration of a cardiac cycle is about $\frac{8}{10}$ of a second, made up as follows :

Atrial systole, $\frac{1}{10}$.	Atrial diastole, $\frac{7}{10}$.
Ventricular systole, $\frac{3}{10}$.	Ventricular diastole, $\frac{5}{10}$.
Total systole, $\frac{4}{10}$.	*Complete diastole*, $\frac{4}{10}$.

The rhythmical action of the heart is *muscular* in origin—that is to say, the heart-muscle possesses the inherent property of contraction apart from any nervous stimulation. The more embryonic the muscle the better is it able to initiate the contraction wave, and the normal systole of the heart starts at the sinu-atrial node, where the muscle is most embryonic in nature : for this reason the sinu-atrial node has been called the 'pacemaker' of the heart. A slight pause occurs between the systole of the atria and that of the ventricles. This is due to the fact that the contraction of the ventricles is excited by an impulse conveyed by the atrioventricular bundle, conduction along the fibres of which is relatively slow. The nerves, although not concerned in originating the contractions of the heart-muscle, play an important rôle in regulating their force and frequency in order to subserve the physiological needs of the organism.

Applied Anatomy.—Wounds of the heart are often immediately fatal, because, when blood is effused into the pericardial sac, it presses on the thin-walled atria and mechanically hampers the cardiac muscle. Such penetrating wounds, however, are not necessarily fatal, as many cases have been recorded in which the wound has been sutured successfully. On the other hand, non-penetrating wounds may prove fatal, if one of the coronary arteries has been divided or if pericarditis supervenes.

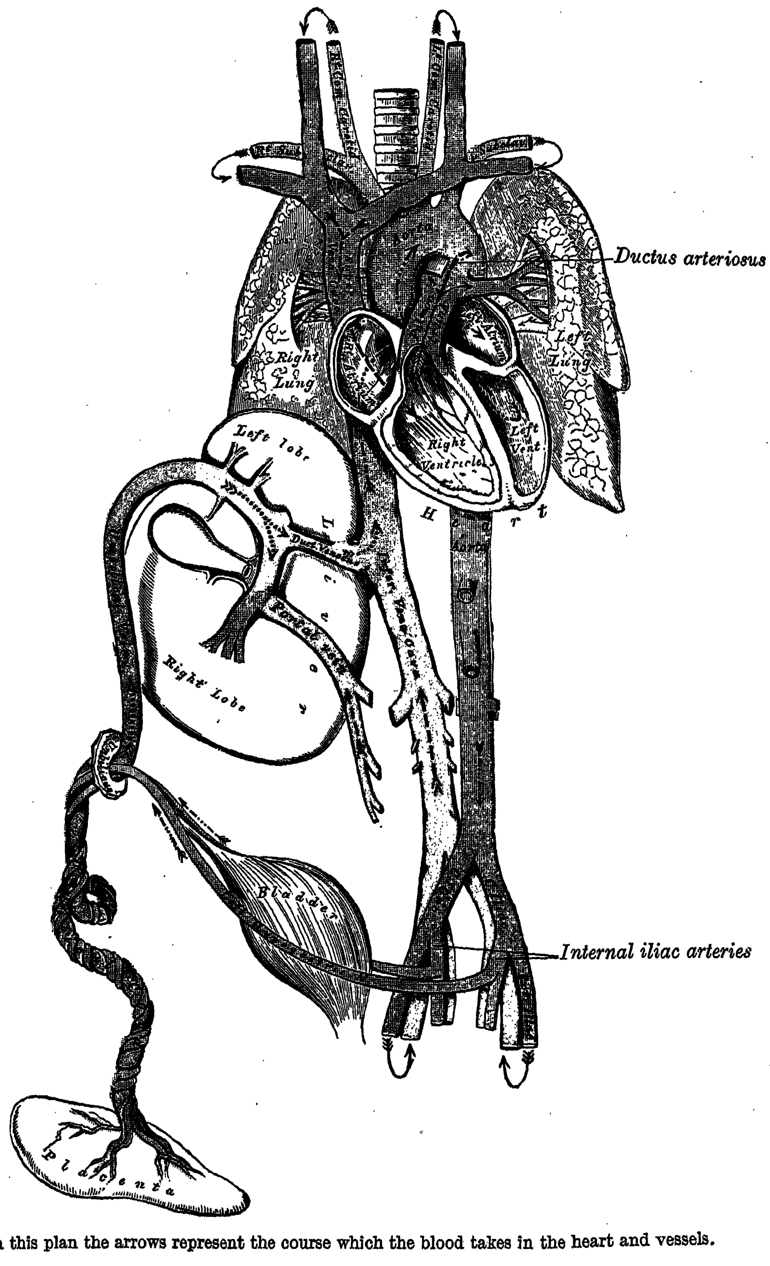
The Fœtal Circulation (fig. 693)

The fœtal blood is carried to the placenta by the umbilical arteries, and returned from the placenta to the fœtus by the two umbilical veins. These veins unite in the umbilical cord to form a single vein (vena umbilicalis impar) which enters the abdomen at the umbilicus, and passes in the free margin of the falciform ligament to the visceral surface of the liver, where it gives off two or three branches to the left lobe, and others to the lobus quadratus. At the porta hepatis it joins the left branch of the portal vein, from which, opposite this point, a large vessel arises and ascends on the posterior aspect of the liver to join the left hepatic vein immediately before that vessel opens into the inferior vena cava. This vessel is termed the *ductus venosus*. During fœtal life the portal vein is small compared with the umbilical vein, and the proximal and distal parts of its left branch actually function as branches of the latter vessel (fig. 693). It will be seen therefore that the blood conveyed by the left umbilical vein passes to the inferior vena cava in three different ways. Some enters the liver directly and is carried to the inferior vena cava by the hepatic veins ; a considerable quantity circulates through the liver with the portal venous blood, before entering the inferior vena cava by the hepatic veins ; the remainder passes into the inferior vena cava through the ductus venosus.

In the inferior vena cava, the blood carried by the ductus venosus and hepatic veins mixes with that returning from the lower limbs and from the abdominal wall It enters the right atrium, and, guided by the valve of the inferior vena cava, passes through the foramen ovale into the left atrium, where it mingles with a small quantity of blood returned from the lungs by the pulmonary veins. From the left atrium it passes into the left ventricle, and from that cavity into the aorta, through the branches of which it is probably distributed almost entirely to the head and the upper limbs, only a small quantity being carried into the descending aorta. The blood from the head and the upper limbs is returned by the superior vena cava to the right atrium, where it mixes with a small portion of that returned by the inferior vena cava. From the right atrium the blood passes into the right ventricle, and thence into the pulmonary trunk. The lungs of the fœtus being inactive, only a small quantity of the blood conveyed by the pulmonary trunk is distributed to them by the

right and left pulmonary arteries, and returned by the pulmonary veins to the left atrium: the greater part passes through the ductus arteriosus into the aorta, where it mixes with the small quantity of blood transmitted by the left ventricle into this part of the aorta. It descends through the aorta and

FIG. 693.—A plan of the fœtal circulation.



In this plan the arrows represent the course which the blood takes in the heart and vessels.

is in part distributed to the lower limbs and to the viscera of the abdomen and pelvis, but most of it is conveyed by the umbilical arteries to the placenta.

From the preceding account of the circulation of the blood in the fœtus the following facts will be inferred: 1. The placenta serves the purposes of nutrition and excretion, receiving the impure blood from the fœtus, and returning it purified and charged with nutritive material. 2. Some of the blood of the left

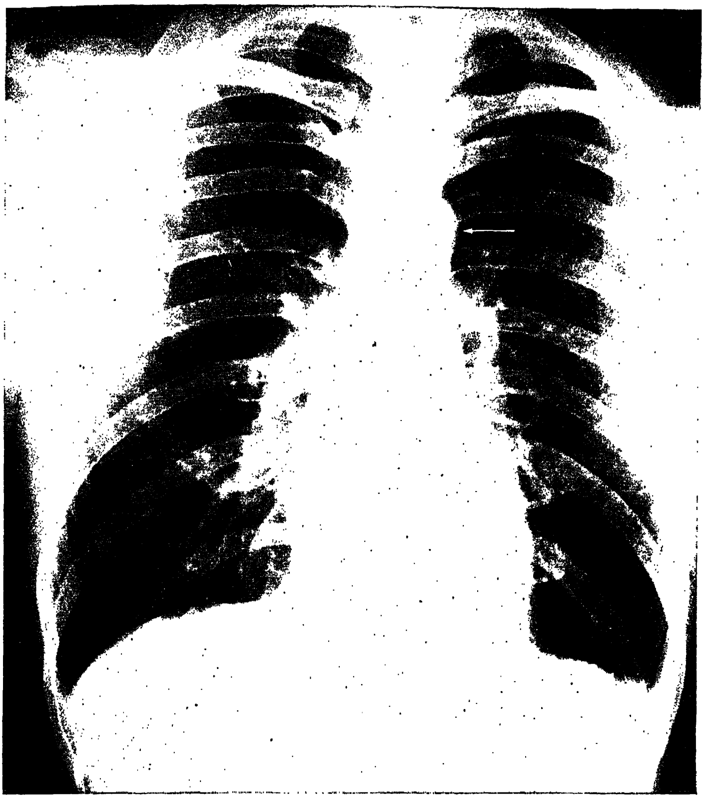


Fig. 1.—Radiograph of heart. Anterior view. The arrow points to the arch of the aorta.

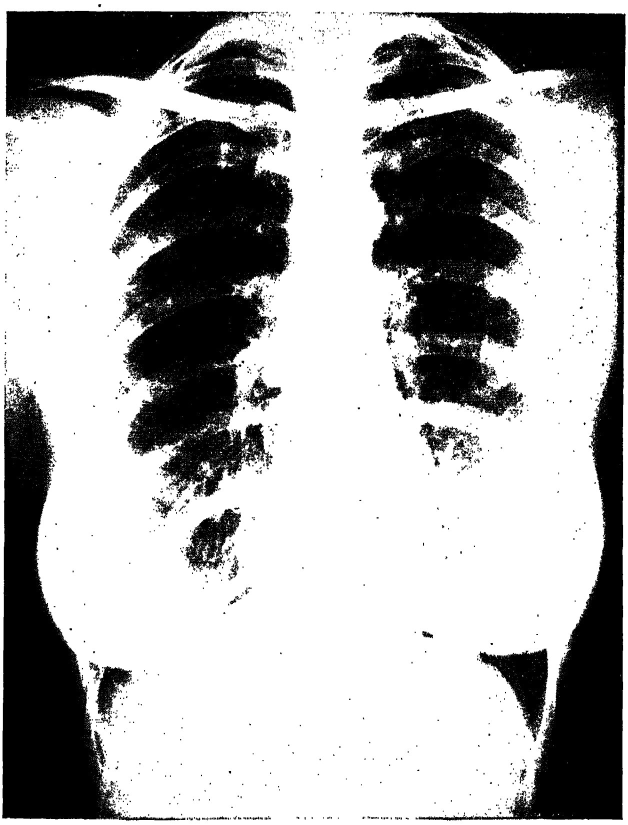


Fig. 2.—Radiograph of the thorax, showing the shadows thrown by the female breasts.

PLATE XIV

Radiograph showing the œsophagus during the passage of a barium meal. Note that in the upper part of the œsophagus longitudinal folds in the mucous membrane can be identified. The upper arrow points to the shadow of the right bronchus; the lower arrow indicates the tenth thoracic vertebra. Note that the lower part of the œsophagus inclines forwards away from the vertebral column.

umbilical vein traverses the liver before entering the inferior vena cava; this is correlated with the relatively large size of the liver, especially at an early period of fœtal life. 3. Only the pulmonary veins open directly into the left atrium, and the volume of blood which enters it from this source is very small. On the other hand, the volume of the blood entering the right atrium is much greater, and the pressure within that chamber is much higher than the pressure in the left atrium. As a result, the flap-like septum primum (p. 141) is thrust over to the left (fig. 184, *D*) and the passage of blood from the right to the left side of the heart is effected easily. The valve of the inferior vena cava is placed so as to enable it to direct the current of blood which issues from that vessel to the foramen ovale and so to the left atrium, whereas the blood entering the right atrium from the superior vena cava passes directly into the right ventricle. At an early period of fœtal life it is probable that these two streams are quite distinct, for the inferior vena cava opens almost directly into the left atrium, and the valve of the inferior vena cava would exclude the current from the right ventricle. At a later period, as the separation between the two atria becomes more marked, it is probable that some mixture of the two streams takes place. 4. The pure blood carried from the placenta to the fœtus, mixed with the blood from the portal vein and inferior vena cava, passes almost directly to the arch of the aorta, and is distributed by the branches of that vessel to the head and the upper limbs. 5. The blood contained in the descending aorta, chiefly derived from that which has already circulated through the head and the upper limbs, together with a small quantity from the left ventricle, is distributed to the abdomen and the lower limbs.

The Changes in the Vascular System at Birth

At birth, when respiration is established, an increased amount of blood from the pulmonary trunk passes through the pulmonary arteries to the lungs, and a correspondingly increased amount returns by the pulmonary veins to the left atrium. The pressures within the two atria become equalised, and the foramen ovale, which is valve-like in character, is closed by the apposition, and later by the fusion, of the septum primum to the septum secundum (fig. 184). Not infrequently the fusion is incomplete and a small communication between the two atria may persist throughout life. Such a communication has no functional significance as, owing to the equality of the intra-atrial pressures and the valve-like arrangement of the opening, no blood can pass from one side to the other.

When the umbilical cord is ligatured and the placental circulation is cut off, the umbilical vein becomes thrombosed and is gradually converted into a fibrous cord which constitutes the *ligamentum teres* of the liver. The ductus venosus also becomes obliterated, but the reasons for its obliteration are not so obvious and may possibly be associated with the alteration in the position of the liver brought about by the establishment of the respiratory movements. Its fibrous remnant is found in the adult as the *ligamentum venosum* of the liver.

The closure of the ductus arteriosus is an essential but, probably, a gradual process, taking some months to complete. Before birth the vessel is the direct continuation of the pulmonary trunk, but when the right and left pulmonary arteries dilate to carry additional blood to the lungs, it becomes a ‘ backwater ’ and its direction is altered by the rotation of the heart to the left (p. 146). Ultimately it forms an impervious cord which connects the left pulmonary artery near its origin to the arch of the aorta and is termed the *ligamentum arteriosum*. Following ligature of the umbilical cord, the umbilical or hypogastric arteries become thrombosed from the point at which they give off their last branches—the superior vesical arteries—to the umbilicus, and are subsequently converted into fibrous cords, which lie in the extraperitoneal fatty tissue of the lower part of the anterior abdominal wall and produce the *lateral umbilical folds* of peritoneum.

THE ARTERIES

The distribution of the systemic arteries is like a highly branched tree, the common trunk of which, formed by the aorta, commences at the left ventricle, while the smallest ramifications extend to the viscera and to the peripheral parts of the body. Arteries are found in all parts of the body, except in the hairs, nails, epidermis, cartilages and corneæ ; the larger trunks usually occupy protected situations, running, in the limbs, along the flexor surfaces, where they are less exposed to injury.

There is considerable variation in the mode of division of the arteries: occasionally a short trunk subdivides into several branches at the same point, as in the cœliac artery and the thyrocervical trunk ; more usually the vessel gives off several branches in succession, and still continues as the main trunk, as in the arteries of the limbs.

A branch of an artery is smaller than the trunk from which it arises ; but if an artery divides into two branches, the combined sectional area of the two vessels is, in nearly every instance, somewhat greater than that of the trunk ; and the combined sectional area of all the arterial branches greatly exceeds that of the aorta.

Arteries do not always end in capillaries ; in many cases they unite with one another, forming what are called *anastomoses*. Anastomosis between trunks of nearly equal size is found in the brain, where the two vertebral arteries unite to form the basilar artery, and the two anterior cerebral arteries are connected by the anterior communicating artery ; and in the abdomen, where the intestinal arteries have free anastomoses between their larger branches. In the limbs, the anastomoses are largest and most numerous around the joints ; the branches arising from an artery above a joint uniting with branches from the vessels below it. These anastomoses are of considerable interest to the surgeon, as it is by their enlargement that a *collateral circulation* is established after the application of a ligature to a main artery. From the practical point of view, the importance of any individual arterial anastomosis depends on the distance which separates the points of origin of the anastomosing vessels. The smaller branches of arteries anastomose more frequently than the larger ; and between the smallest twigs these anastomoses may be so numerous that they constitute a close network. In certain regions of the body, for example, the spleen, the kidney and certain parts of the brain, there are arteries which have no anastomoses with their neighbours except through the agency of the capillaries, and are therefore called *end-arteries*. If an artery of this type be occluded, serious nutritional disturbances resulting in death (necrosis) will occur in the tissues supplied by the vessel.

The Pulmonary Trunk

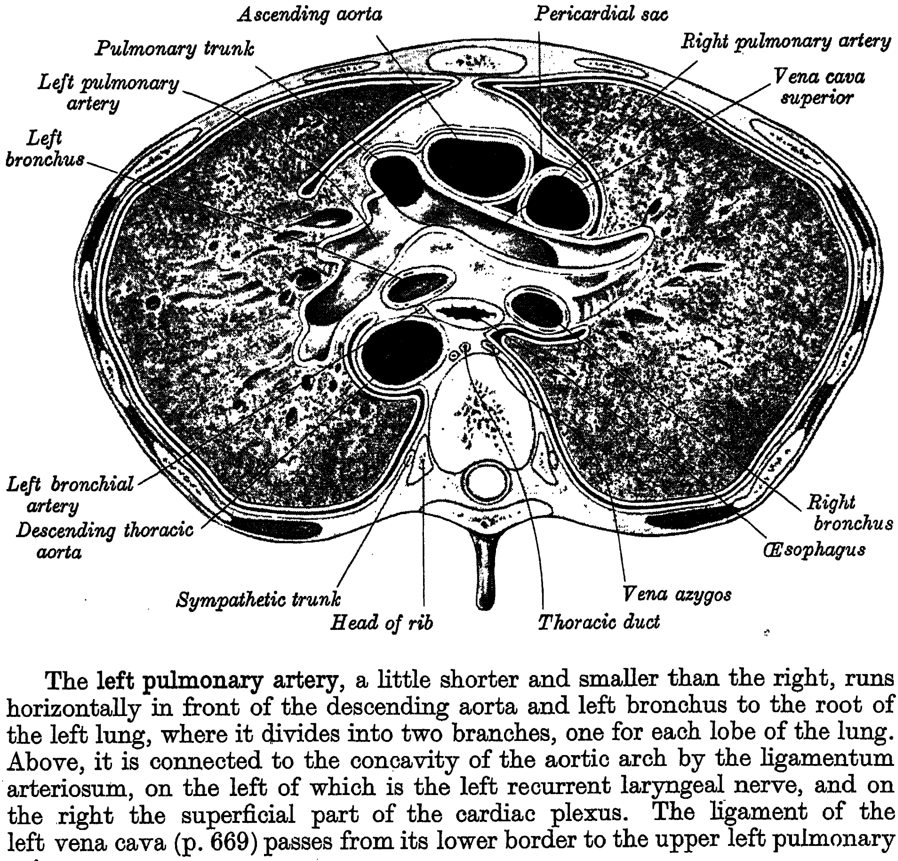
The **pulmonary trunk** (figs. 695, 697) conveys deoxygenated blood from the right ventricle of the heart to the lungs. It is about 5 cm. in length and 3 cm. in diameter, and arises from the infundibulum (conus arteriosus) of the right ventricle. It runs upwards and backwards, at first in front of the ascending aorta, and then to its left side. In the concavity of the aortic arch it divides, at the level of the fifth thoracic vertebra, into right and left pulmonary arteries, which are of nearly equal size.

Relations.—The whole of the pulmonary trunk is contained within the pericardium. It and the ascending aorta are enclosed in a common tube of the visceral layer of the serous pericardium. The fibrous layer of the pericardium is gradually lost upon the external coats of the two pulmonary arteries. *In front*, the pulmonary trunk is separated from the sternal end of the left second intercostal space by the pleura, the left lung and the pericardium. *Behind*, it rests at first upon the ascending aorta and the left coronary artery ; at a higher level it lies in front of the left atrium, and the ascending aorta is on its right side. The auricle of the corresponding atrium and a coronary

artery lie on each side of its origin. The superficial part of the cardiac plexus lies between the division of the pulmonary trunk and the arch of the aorta.

The **right pulmonary artery**, slightly longer and larger than the left, runs horizontally to the right, behind the ascending aorta, superior vena cava and upper right pulmonary vein, and in front of the œsophagus and the right bronchus, to the root of the right lung, where it divides into two branches. The lower and larger of these is distributed to the middle and lower lobes of the lung; the upper and smaller accompanies the eparterial bronchus to the upper lobe.

FIG. 694.—A transverse section through the thorax, showing the relations of the pulmonary trunk, etc.



The **left pulmonary artery**, a little shorter and smaller than the right, runs horizontally in front of the descending aorta and left bronchus to the root of the left lung, where it divides into two branches, one for each lobe of the lung. Above, it is connected to the concavity of the aortic arch by the ligamentum arteriosum, on the left of which is the left recurrent laryngeal nerve, and on the right the superficial part of the cardiac plexus. The ligament of the left vena cava (p. 669) passes from its lower border to the upper left pulmonary vein.

The terminal branches of the pulmonary arteries are described with the anatomy of the lungs.

Applied Anatomy.—Embolism of the pulmonary trunk by a clot of blood coming from the right side of the heart in patients with heart-disease, or from a thrombosed vein in cases, for example, of influenza, enteric fever, puerperal sepsis, or fractured limbs, is a common cause of sudden or rapid death.

THE AORTA

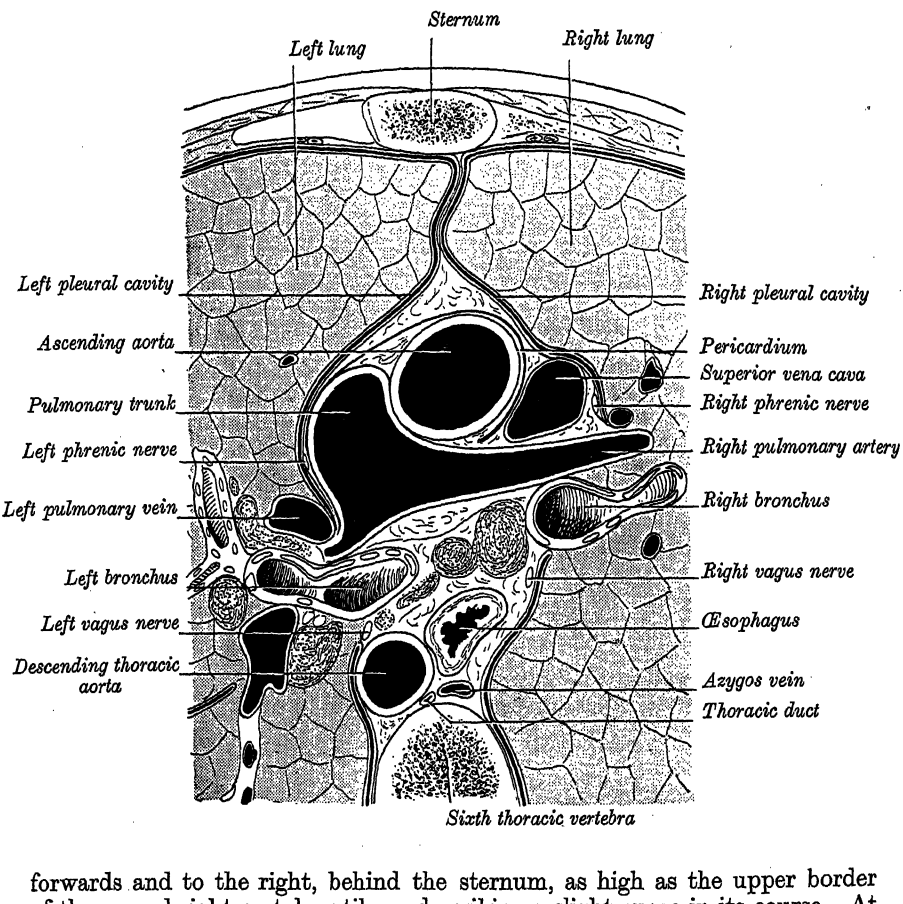
The **aorta** is the main trunk of the series of vessels which convey the oxygenated blood to the tissues of the body. It begins at the upper part of the left ventricle, where it is about 3 cm. in diameter, and after ascending for a short distance, arches backwards and to the left, over the root of the left lung; it then descends within the thorax on the left side of the vertebral column,

and enters the abdominal cavity through the aortic opening in the diaphragm. Considerably diminished in size (about 1·75 cm. in diameter), it ends, a little to the left of the median plane, at the level of the lower border of the fourth lumbar vertebra, by dividing into the right and left common iliac arteries. Hence it is described in several portions, viz. the *ascending aorta*, the *arch of the aorta*, and the *descending aorta*, the last being divided into the *descending thoracic* and *abdominal aortæ*.

The Ascending Aorta

The **ascending aorta** (figs. 674, 697) is about 5 cm. long. It begins at the base of the left ventricle, on a level with the lower border of the third costal cartilage, behind the left half of the sternum; it passes obliquely upwards,

Fig. 695.—A transverse section through the mediastinum at the level of the upper part of the body of the sixth thoracic vertebra.



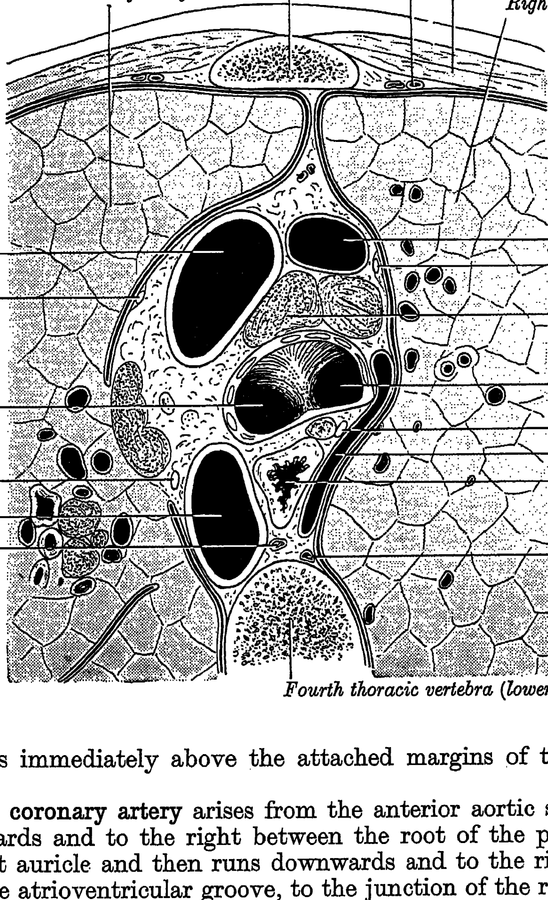
forwards and to the right, behind the sternum, as high as the upper border of the second right costal cartilage, describing a slight curve in its course. At its origin, opposite the cusps of the aortic valve, there are three small dilatations called the aortic sinuses. At the union of the ascending aorta with the aortic arch the calibre of the vessel is slightly increased, owing to a bulging of its right wall. This dilatation is termed the *bulb of the aorta*, and, on transverse section at this level, the vessel presents a somewhat oval outline.

Relations.—The ascending aorta is contained within the fibrous pericardium, and is enclosed in a tube of the serous pericardium, common to it and the pulmonary trunk. *Anteriorly* its lower part is related to the infundibulum (conus arteriosus) of the right ventricle, the commencement of the pulmonary

trunk and the auricle of the right atrium ; higher up, it is separated from the sternum by the pericardium, the right pleura, the anterior margin of the right lung, some loose areolar tissue and the remains of the thymus ; *posteriorly*, it is related successively to the left atrium, the right pulmonary artery and the right bronchus ; on its *right side*, to the superior vena cava and right atrium, the former lying partly behind it ; on its *left side*, to the left atrium and the pulmonary trunk.

Branches.—The branches of the ascending aorta are the right and left coronary arteries (figs. 677, 698), which supply the heart ; they arise from the

Fig. 696.—A transverse section through the mediastinum at the level of the lower part of the body of the fourth thoracic vertebra.



aortic sinuses immediately above the attached margins of the cusps of the aortic valve.

The **right coronary artery** arises from the anterior aortic sinus. It passes at first forwards and to the right between the root of the pulmonary trunk and the right auricle and then runs downwards and to the right in the right portion of the atrioventricular groove, to the junction of the right and inferior margins of the heart. Here it turns to the left and runs on the back of the heart, as far as the inferior interventricular groove, where it anastomoses with the left coronary artery. The right coronary artery supplies branches to the right atrium and, by means of a marginal branch (fig. 698), to both surfaces of the right ventricle. Near its termination it gives off an *interventricular branch*, which runs forwards in the inferior interventricular groove, supplies branches to both ventricles and anastomoses near the apex of the heart with the interventricular branch of the left coronary artery.

The **left coronary artery**, larger than the right, arises from the left posterior aortic sinus and, after a short course forwards between the pulmonary trunk and the left auricle, turns to the left in the atrioventricular groove. It then passes backwards round the left margin of the heart and accompanies the

coronary sinus as far as the interventricular groove, where it anastomoses with the right coronary artery. It supplies branches to the left atrium and the base of the left ventricle. At the point where it turns to the left, the left coronary artery gives off a large *interventricular branch*, which descends in the anterior interventricular groove, to the incisura apicis cordis. This branch supplies both ventricles and anastomoses with the interventricular branch of the right coronary artery. In many subjects it turns round the apex of the heart and runs backwards for a variable distance in the inferior interventricular groove (fig. 698).

There is a very free anastomosis between the minute branches and between the capillaries of the two coronary arteries in the substance of the heart.*

Peculiarities.—Very rarely the coronary arteries arise by a common trunk; or their number may be increased to three or four. The areas of distribution of the two arteries on the diaphragmatic surface of the heart are subject to considerable variation.

Applied Anatomy.—The sudden blocking of a coronary artery by an embolus, or its more gradual obstruction by arterial disease or thrombosis, is a common cause of sudden death in persons past middle age. If the obstruction to the passage of blood is incomplete, the patient may suffer from *angina pectoris*, a condition associated with agonising pain in the precordial region and down the left arm.

The Arch of the Aorta

The **arch of the aorta** (figs. 697, 699) connects the ascending with the descending aorta; it begins behind the manubrium sterni at the level of the upper border of the second right sternocostal articulation, and runs at first upwards, backwards and to the left in front of the trachea; it is then directed backwards on the left side of the trachea, and finally passes downwards on the left side of the body of the fourth thoracic vertebra, at the lower border of which it is continuous with the descending aorta. It thus forms two curvatures: one with its convexity upwards, the other with its convexity forwards and to the left. Its upper border is usually about the level of the middle of the manubrium sterni.

Relations.—The arch of the aorta is covered *anteriorly* by the pleuræ and anterior margins of the lungs. As the vessel runs backwards, its *left* side is in contact with the left lung and pleura. Passing downwards on the left side of this part of the arch there are four nerves; in order from before backwards these are: the left phrenic, the lower of the cervical cardiac branches of the left vagus, the superior cervical cardiac branch of the left sympathetic, and the trunk of the left vagus. As the left vagus crosses the arch it gives off its recurrent laryngeal branch, which hooks round below the vessel to the left of the ligamentum arteriosum and then passes upwards on its right side. The left superior intercostal vein runs obliquely upwards and forwards on the left side of the arch, crossing superficial to the vagus but deep to the phrenic nerve (fig. 697). On the *right* are the deep part of the cardiac plexus, the left recurrent laryngeal nerve, and the œsophagus; the trachea lies behind and to the right of the vessel. *Above*, the innominate, left common carotid and left subclavian arteries arise from the convexity of the arch and are crossed close to their origins by the left innominate vein. *Below*, the arch is related to the bifurcation of the pulmonary artery, the left bronchus, the ligamentum arteriosum, the superficial part of the cardiac plexus and the left recurrent laryngeal nerve. As already stated (p. 691), the ligamentum arteriosum connects the commencement of the left pulmonary artery to the inferior aspect of the aortic arch.

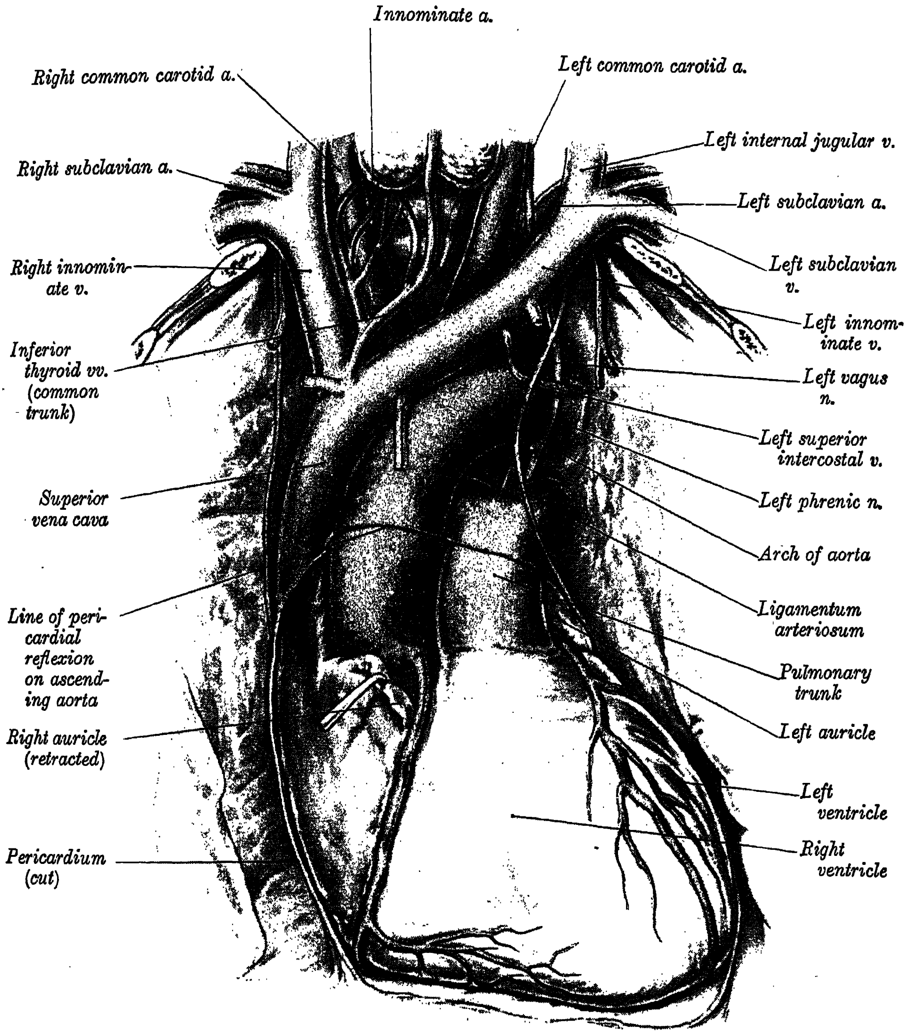
In the fœtus the lumen of the aorta is considerably narrowed between the origin of the left subclavian artery and the attachment of the ductus arteriosus, forming what is termed the *aortic isthmus*, while immediately beyond the ductus arteriosus the vessel presents a fusiform dilatation which His named the *aortic spindle*—the point of junction of the two parts being marked in the concavity of the arch by an indentation or angle. These conditions persist, to some extent,

* Consult in this connexion *The Blood Supply of the Heart*, by Louis Gross, 1921.

in the adult, where His found that the average diameter of the spindle exceeded that of the isthmus by 3 mm.

Peculiarities.—The summit of the arch of the aorta is usually about 2·5 cm. below the upper border of the sternum ; but it may reach nearly to the top of the bone. Occasionally it is found 4 cm., more rarely from 5 to 8 cm., below this point. Sometimes the aorta arches over the root of the right lung (right aortic arch) instead of over that of the left, and passes down on the right side of the vertebral column, a condition which is normal

FIG. 697.—The heart and great vessels.



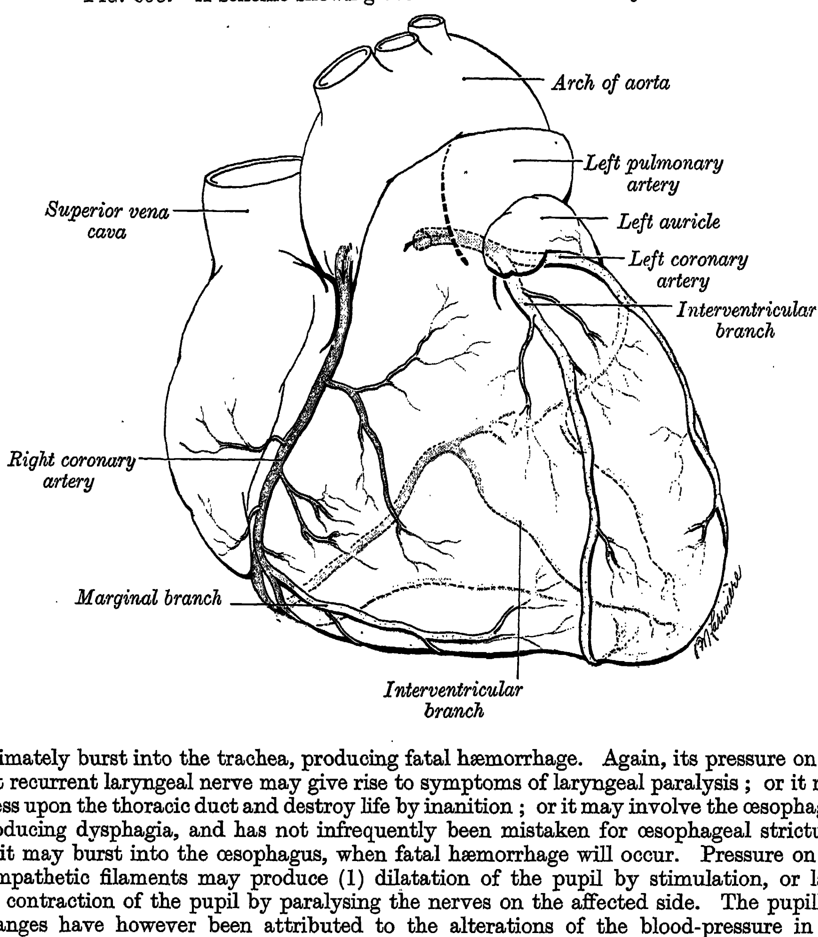
in birds. In such cases there is usually a transposition of the thoracic and of the abdominal viscera. Less frequently the aorta, after arching over the root of the right lung, passes behind the œsophagus to gain its usual position on the left side of the vertebral column ; this peculiarity is not accompanied by transposition of the viscera. The aorta occasionally divides, as in some quadrupeds, into an ascending and a descending trunk, the former of which is directed vertically upwards, and subdivides into three branches, to supply the head and upper limbs. Sometimes the aorta subdivides near its origin into two branches, which soon reunite ; in these cases the œsophagus and trachea usually pass through the interval between the two branches ; this is the normal condition of the vessel in the reptilia and is due to persistence of a part of the right dorsal aorta which usually disappears (fig. 190).

Applied Anatomy.—The ascending aorta and the arch of the aorta are frequent sites of aneurysm.

Aneurysm of the ascending aorta in a majority of cases affects the anterior sinus, owing to the fact that the reflux of blood which follows the closing of the aortic valve is directed chiefly against the anterior wall of the vessel. If the aneurysmal sac projects forwards it may destroy part of the sternum and the costal cartilages, usually on the right side, and appear as a pulsating tumour on the front of the chest. In other cases it may compress or open into the right lung, bronchi, or trachea; it may burst into the pericardium (a common cause of death in these aneurysms), or may compress the right atrium, the pulmonary trunk and the adjoining part of the right ventricle, and open into one or other of these structures. It may press upon the superior vena cava or the innominate veins, causing great venous engorgement in their tributaries; an aneurysm has occasionally perforated into the superior vena cava, setting up an arteriovenous aneurysm.

Aneurysm of the aortic arch usually involves the posterior part of the vessel. It may press upon the trachea and give rise to the sign known as 'tracheal tugging,' impede the breathing, or produce cough, dyspnœa, stridor, bronchiectasis, or hæmoptysis, or it may

FIG. 698.—A scheme showing the course of the coronary arteries.



ultimately burst into the trachea, producing fatal hæmorrhage. Again, its pressure on the left recurrent laryngeal nerve may give rise to symptoms of laryngeal paralysis; or it may press upon the thoracic duct and destroy life by inanition; or it may involve the œsophagus, producing dysphagia, and has not infrequently been mistaken for œsophageal stricture; or it may burst into the œsophagus, when fatal hæmorrhage will occur. Pressure on the sympathetic filaments may produce (1) dilatation of the pupil by stimulation, or later (2) contraction of the pupil by paralysing the nerves on the affected side. The pupillary changes have however been attributed to the alterations of the blood-pressure in the carotid artery on the affected side—lowering of pressure leading to partial collapse of the tortuous vessels of the iris and dilatation of the pupil, increase of pressure tending to straighten out these vessels and diminish the pupillary aperture. Again, the innominate artery, or the subclavian, or left carotid, may be so obstructed by clots as to produce weakness, or even a disappearance, of the pulse in one or the other wrist, or in the left superficial temporal artery; or the tumour may present itself at or above the manubrium, generally either in the median line, or the right of the sternum, and may simulate an aneurysm of one of the arteries of the neck.

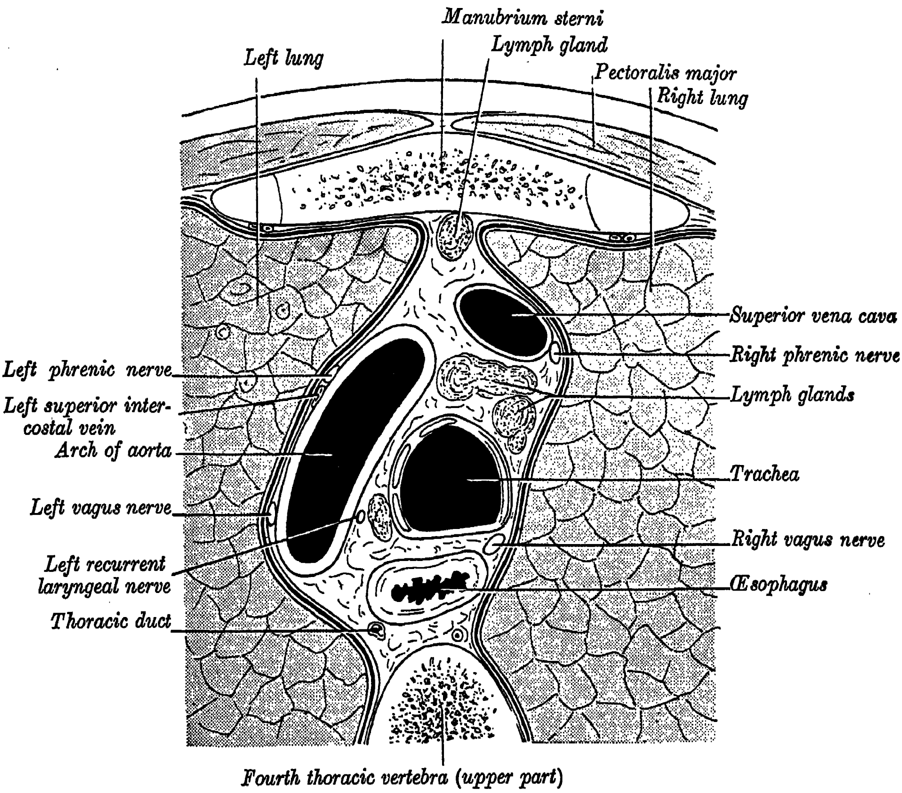
Many of the physical signs of an aortic aneurysm may be simulated with extraordinary fidelity by the pulsation or throbbing of a distended and elastic aorta. This condition may be met with in young persons with aortic regurgitation and greatly hypertrophied hearts, in patients who are of a neurotic or hysterical temperament, and in cases of Graves's disease or of marked anæmia. The condition is known as dynamic dilatation of the aorta, and in no way threatens life.

Branches (figs. 697, 700).—Three branches are given off from the upper aspect of the arch of the aorta, viz.: the innominate, the left common carotid and the left subclavian.

Peculiarities.—The branches may spring from the commencement of the arch or upper part of the ascending aorta; or the distance between them at their origins may be increased or diminished, the most frequent change in this respect being the approximation of the left carotid to the innominate artery.

The number of the primary branches may be reduced to one; more commonly there are two, the left carotid arising from the innominate artery, or (more rarely) the carotid and subclavian arteries of the left side arising from a left innominate artery. But the

FIG. 699.—A transverse section through the mediastinum at the level of the upper part of the body of the fourth thoracic vertebra.



number may be increased to four, through the right carotid and subclavian arteries arising directly from the aorta; in most of these cases the right subclavian arises from the left end of the arch and passes to the right behind the œsophagus (see also p. 149). Another common variation in which there are four primary branches is that where the left vertebral artery arises from the arch of the aorta between the left carotid and subclavian arteries. Lastly, the number of trunks may be increased to five or six; very rarely, the external and internal carotid arteries arise separately, the common carotid being absent on one or both sides. In some few cases six branches have been found, and this condition is associated with the origin of both vertebral arteries from the arch.

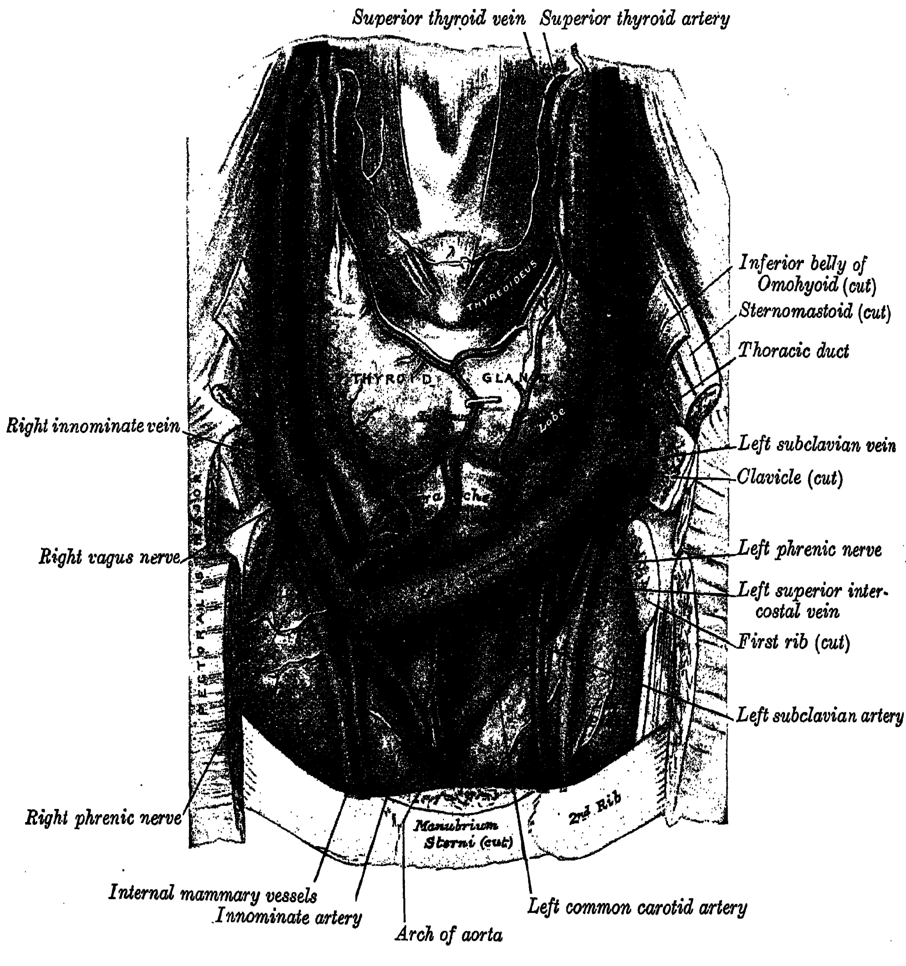
When the aorta arches over to the right side, the arrangement of the three branches is reversed: there is a left innominate artery, and the right carotid and right subclavian arise separately. In other cases, where the aorta takes its usual course, the two carotids may be joined in a common trunk, and the subclavians arise separately from the arch, the right subclavian generally arising from the left end of the arch.

Other arteries may spring from the arch of the aorta. Of these the most common are the bronchial (one or both), and the thyroidea ima; the internal mammary and the inferior thyroid have been seen to arise from it.

The Innominate Artery (figs. 697, 700, 701, 703)

The **innominate artery** is the largest branch of the arch of the aorta, and is from 4 to 5 cm. in length. It arises from the convexity of the arch of the aorta, posterior to the centre of the manubrium sterni ; it passes obliquely upwards, backwards and to the right, lying at first in front of the trachea and

Fig. 700.—Dissection of the lower part of the neck, and the upper part of the thorax. Anterior aspect.



then on its right side. At the level of the upper border of the right sterno-clavicular joint it divides into the right common carotid and right subclavian arteries.

Relations.—*Anteriorly* it is separated from the manubrium sterni by the Sternohyoid and Sternothyroid, the remains of the thymus, the left innominate and right inferior thyroid veins, which cross its root, and sometimes the cardiac branches of the right vagus nerve. *Posteriorly* it is related to the trachea below, and the right pleura above ; on the *right side*, to the right innominate vein, the upper part of the superior vena cava, and the pleura ; and on the *left side*, the remains of the thymus, the origin of the left common carotid artery, the inferior thyroid veins, and at a higher level the trachea.

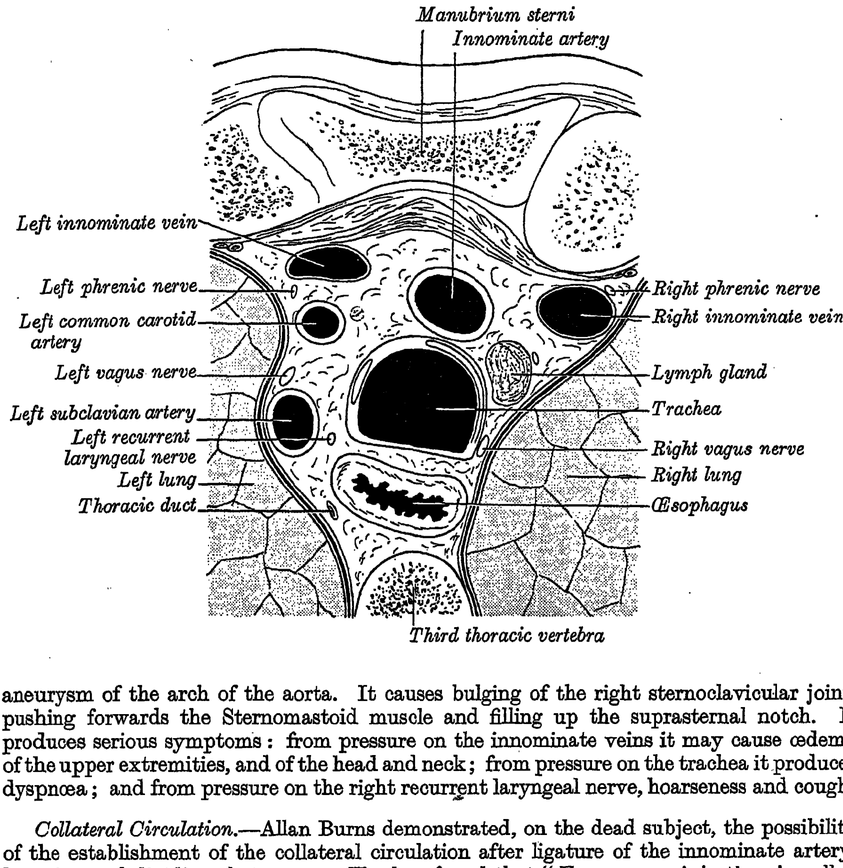
Branches.—The innominate artery is usually devoid of branches other than its terminal ones, but occasionally the *thyroidea ima* arises from it, and sometimes it gives off a *thymic* or a *bronchial branch.*

The **thyroidea ima**, small and inconstant, ascends, in front of the trachea to the isthmus of the thyroid gland, in which it ends. It occasionally arises from the aorta, or from the right common carotid, subclavian or internal mammary arteries.

Peculiarities.—The innominate artery sometimes projects above the upper border of the manubrium sterni. It may divide above the level of the sternoclavicular joint, less frequently below it. When the aortic arch is on the right side, the innominate artery is directed to the left side of the neck.

Applied Anatomy.—The innominate artery may be wounded in performing the operation of low tracheotomy, or a badly placed tracheotomy tube may ulcerate into the vessel. Aneurysm of the innominate artery not infrequently occurs as an accompaniment of

Fig. 701.—A transverse section through the mediastinum at the level of the body of the third thoracic vertebra.



aneurysm of the arch of the aorta. It causes bulging of the right sternoclavicular joint, pushing forwards the Sternomastoid muscle and filling up the suprasternal notch. It produces serious symptoms: from pressure on the innominate veins it may cause œdema of the upper extremities, and of the head and neck; from pressure on the trachea it produces dyspnœa; and from pressure on the right recurrent laryngeal nerve, hoarseness and cough.

Collateral Circulation.—Allan Burns demonstrated, on the dead subject, the possibility of the establishment of the collateral circulation after ligature of the innominate artery, by tying and dividing that artery. He then found that " Even coarse injection, impelled into the aorta, passed freely by the anastomosing branches into the arteries of the right arm, filling them and all the vessels of the head completely." * The branches by which this circulation is carried on are numerous; thus, all the communications across the median plane between the branches of the carotid arteries of opposite sides are available for the supply of blood to the right side of the head and neck; the anastomosis between the costocervical of the subclavian and the third posterior intercostal (see *infra* on the collateral circulation after obliteration of the descending thoracic aorta) brings the blood, by a free and direct course, into the right subclavian; the numerous connexions between the posterior intercostal arteries and the branches of the axillary and internal mammary arteries assist in the supply of blood to the right arm, while the inferior epigastric from the external iliac, by means of its anastomosis with the internal mammary, compensates for any deficiency in the vascularity of the wall of the chest.

* *Surgical Anatomy of the Head and Neck*, p. 62.

THE ARTERIES OF THE HEAD AND NECK

The principal arteries of the head and neck are the two common carotids; they ascend in the neck and each divides into two branches, viz. (1) the external carotid, supplying the exterior of the head, the face and the greater part of the neck; (2) the internal carotid, supplying to a great extent the parts within the cranial and orbital cavities.

These arteries, together with the veins and nerves which accompany them, are situated in a cleft on each side of the neck. This cleft may be said to possess three walls; a posterior formed mainly by the cervical vertebræ with their attached muscles; a medial consisting of the trachea, œsophagus, thyroid gland, larynx and the constrictor muscles of the pharynx; and an antero-lateral made up of the Sternomastoid with, at different levels, the Omohyoid, and the Digastric and Stylohyoid muscles.

The Common Carotid Arteries

The **common carotid arteries** differ in length and in their mode of origin. The *right* artery begins at the bifurcation of the innominate artery behind the right sternoclavicular joint and is confined to the neck. The *left* artery springs from the highest part of the arch of the aorta immediately behind and to the left of the innominate artery, and therefore consists of a thoracic and a cervical portion.

The **thoracic portion of the left common carotid artery** (figs. 700, 701) ascends from the arch of the aorta to the level of the left sternoclavicular joint, where it is continuous with the cervical portion. It lies at first in front of the trachea, but later inclines to its left side.

Relations.—*In front*, it is separated from the manubrium sterni by the Sternohyoid and Sternothyroid, the anterior portions of the left pleura and lung, the left innominate vein and the remains of the thymus; *behind*, it is related to the trachea, the left subclavian artery, the left edge of the œsophagus, the left recurrent laryngeal nerve and the thoracic duct. On its *right side* it is related below to the innominate artery, and above to the trachea, the inferior thyroid veins and the remains of the thymus; at its *left side* are the left vagus and phrenic nerves, the left pleura and lung.

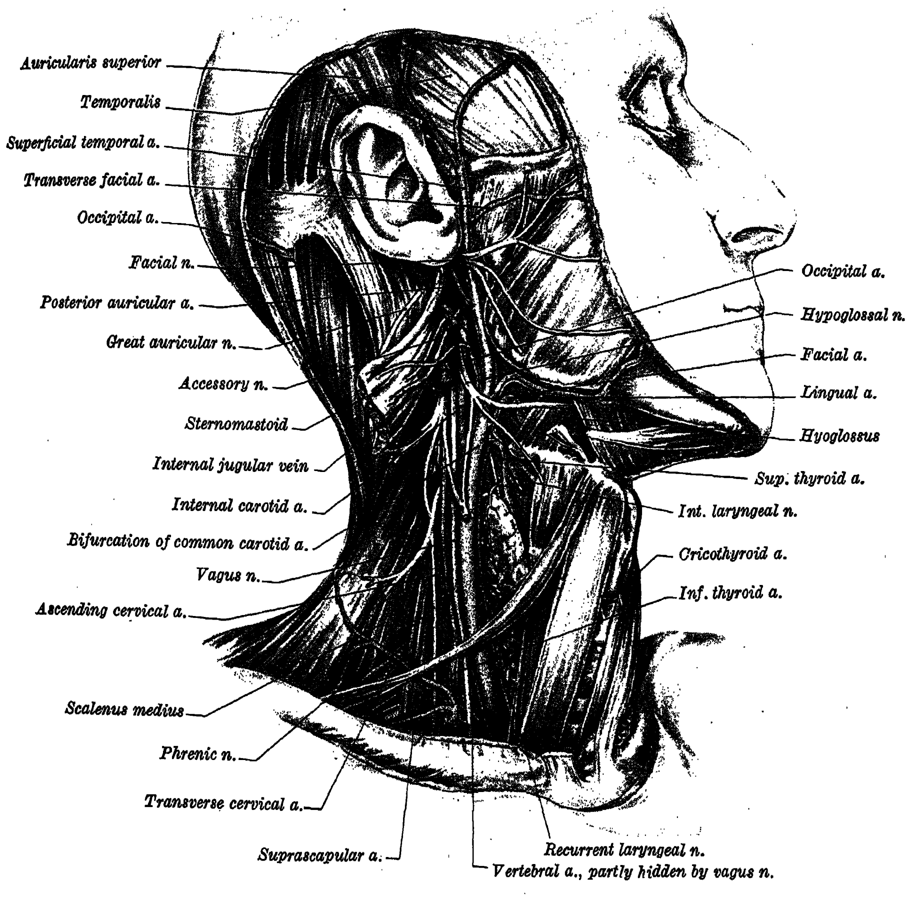
The **cervical portions** of the common carotid arteries resemble each other so closely that one description will apply to both (figs. 702, 704). Each passes obliquely upwards, from behind the sternoclavicular joint, to the level of the upper border of the thyroid cartilage, where it divides into the external and internal carotid arteries. At its point of division the vessel shows a dilatation, termed the *carotid sinus*, which usually involves, and may be restricted to, the proximal part of the internal carotid artery. In this situation the tunica media is thinner than elsewhere and the tunica adventitia contains a large number of sensory nerve-endings, which are derived from the glossopharyngeal (p. 1069) and probably also from the vagus nerves. The *carotid body*, which lies behind the point of division of the common carotid artery, is a small, reddish-brown structure; it is intimately related to the carotid sinus, both topographically and functionally.

At the lower part of the neck the two arteries are separated from each other by a narrow interval which contains the trachea; but at the upper part, the thyroid gland, the larynx, and the pharynx project forwards between the two vessels. The common carotid artery is contained in the carotid sheath (p. 537), which is derived from the deep cervical fascia, and is composed of loose cellular tissue, but the part surrounding the artery is thicker and denser than the rest. This sheath encloses also the internal jugular vein and vagus nerve, the vein lying lateral to the artery, and the nerve between the artery and vein, on a plane posterior to both. The descending branch of the hypoglossal nerve is embedded in its anterior wall (fig. 583).

Relations.—The common carotid artery is crossed superficially, at the level of the cricoid cartilage, by the superior belly of the Omohyoid. Below the

level of this muscle the artery is very deeply seated, being covered with the skin, superficial fascia, Platysma, deep cervical fascia, Sternomastoid, Sternohyoid and Sternothyroid. Above the level of the Omohyoid it is more superficial, being covered merely by the skin, the superficial fascia, Platysma, deep cervical fascia and the medial margin of the Sternomastoid. When the latter muscle is drawn backwards, the artery is seen to be contained in the *carotid triangle* (p. 716); this part of the artery is crossed obliquely, from its medial to its lateral side, by the sternomastoid branch of the superior thyroid

FIG. 702.—A dissection of the right side of the neck, showing the carotid and subclavian arteries and their branches.

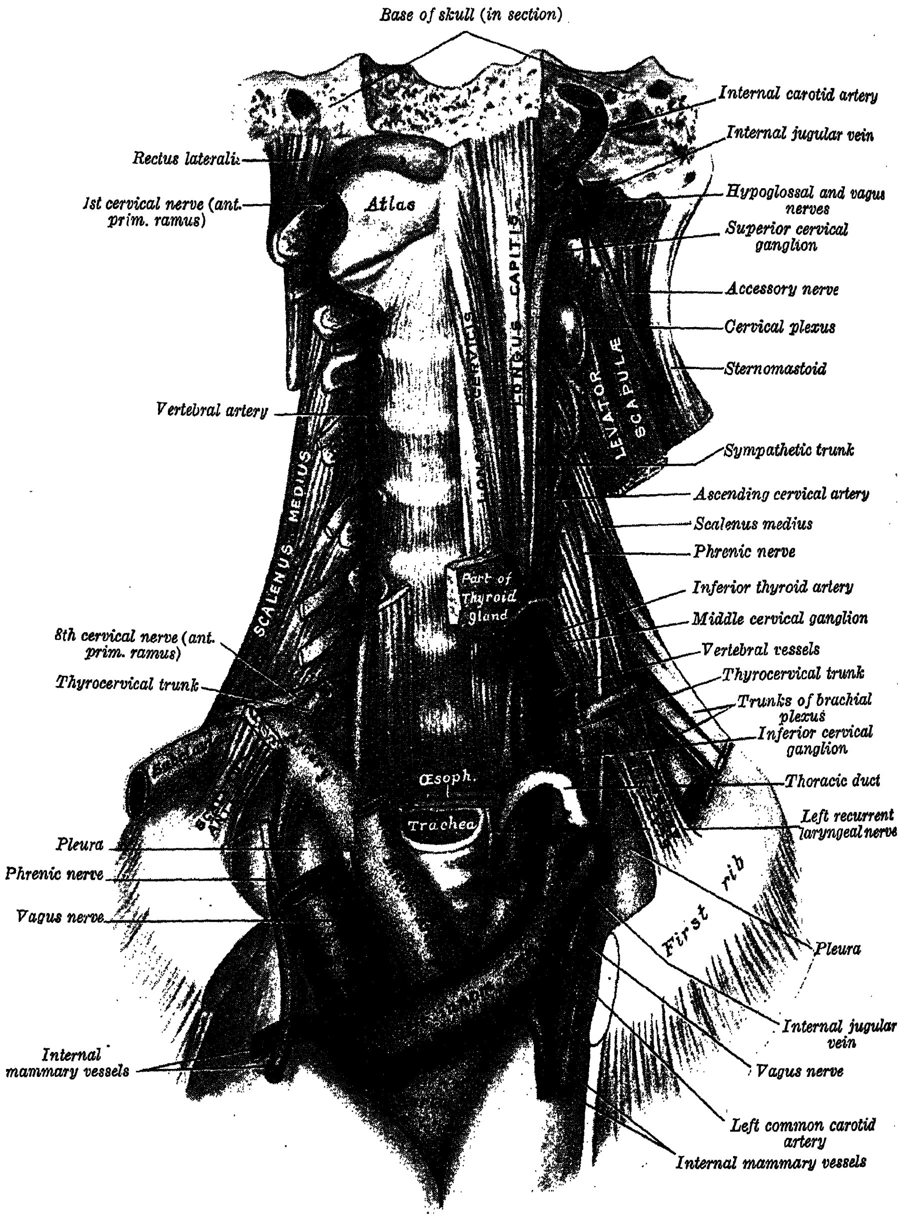


The parotid and submandibular glands and the posterior belly of the digastric have been removed together with the lower part of the internal jugular vein, the upper part of the stylohyoid and the lower part of the sternomastoid, muscle. The upper part of the sternomastoid muscle has been retracted to expose the structures under cover of it.

artery. In front of or within its sheath is the descending branch of the hypoglossal nerve, this branch being joined by the descendens cervicalis nerve, which springs from the second and third cervical nerves and crosses the vessel obliquely. The superior thyroid vein crosses the artery near its termination, and the middle thyroid vein a little below the level of the cricoid cartilage; the anterior jugular vein crosses the artery just above the clavicle, but is separated from it by the Sternohyoid and Sternothyroid muscles. *Behind,* the artery is separated from the transverse processes of the fourth, fifth and sixth cervical vertebræ by the Longus cervicis (Longus colli) and Longus capitis muscles and the origin of the Scalenus anterior, the sympathetic trunk and the ascending cervical artery being interposed between the artery and the muscles. Below the level of the sixth cervical vertebra the common carotid artery lies in the angle between

the Scalenus anterior and the Longus cervicis, anterior to the vertebral vessels, the inferior thyroid and subclavian arteries, and, on the left side, the thoracic duct. *Medial* to it are the œsophagus, trachea, and the lobe of the thyroid

FIG. 703.—A drawing of a dissection of the prevertebral and upper thoracic regions showing the vessels, etc., near the root of the neck, the cervical course of the vertebral artery, and the structures which lie posterior to the left internal jugular vein.



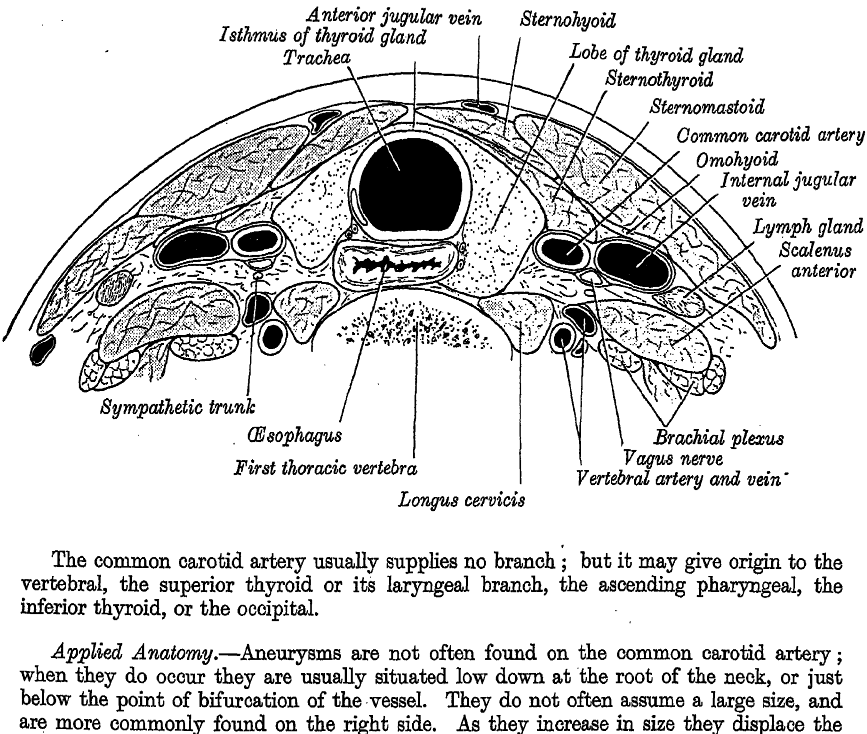
gland (which overlaps it), the inferior thyroid artery and recurrent laryngeal nerve being interposed; higher up, the larynx and pharnyx are medial to the artery. *Lateral* to the artery are the internal jugular vein and vagus nerve.

On the right side, at the lower part of the neck, the recurrent laryngeal nerve crosses obliquely behind the artery; the right internal jugular vein diverges from the artery, but the left vein approaches and often overlaps the lower part of the vessel.

Peculiarities.—In about 12 per cent. of subjects the *right* common carotid artery arises above the level of the upper border of the sternoclavicular joint. It may arise as a separate branch from the arch of the aorta, or in conjunction with the left carotid. The *left* common carotid artery varies in its origin more frequently than the right. In the majority of abnormal cases it arises with the innominate artery; if that artery be absent, the two carotids arise usually by a single trunk. It is rarely joined with the left subclavian, except in cases of transposition of the aortic arch.

Division of the common carotid artery may occur at or about the level of the hyoid bone; more rarely it occurs below the usual level, opposite the middle of the larynx, or the lower border of the cricoid cartilage; one case is described by Morgagni, where the artery was only 4 cm. in length and divided at the root of the neck. Very rarely the artery ascends in the neck without undergoing subdivision, either the external or the internal carotid being wanting. In a few cases the artery has been found absent, the external and internal carotid arteries arising directly from the arch of the aorta; this peculiarity existed on both sides in some instances, on one side only in others.

Fig. 704.—A transverse section through the anterior part of the neck at the level of the body of the first thoracic vertebra.



The common carotid artery usually supplies no branch; but it may give origin to the vertebral, the superior thyroid or its laryngeal branch, the ascending pharyngeal, the inferior thyroid, or the occipital.

Applied Anatomy.—Aneurysms are not often found on the common carotid artery; when they do occur they are usually situated low down at the root of the neck, or just below the point of bifurcation of the vessel. They do not often assume a large size, and are more commonly found on the right side. As they increase in size they displace the trachea and larynx, and therefore dyspnœa becomes a prominent symptom. Dysphagia also may be present from pressure on the œsophagus, especially if the aneurysm is on the left side; and pressure on the recurrent laryngeal nerve may produce hoarseness and laryngeal cough. Pressure on the sympathetic will cause pupillary changes—dilatation of the pupil when the sympathetic is irritated or the arterial blood-supply to the eye is lessened, contraction when the sympathetic has become paralysed; sympathetic irritation may also cause unilateral sweating of the head and neck. Pressure on the superficial branches of the cervical plexus may give rise to pain in the head, face and neck; pressure on the vagus to irregular action of the heart and to asthmatic attacks. It is important to bear in mind that an enlarged lymph gland in the carotid triangle, receiving a transmitted pulsation from the carotid artery, may simulate aneurysm of that vessel, but may be distinguished from it by the character of the pulsation, which is not expansile.

Embolism of the left common carotid artery, or the thrombosis that may follow injury to the wall of the vessel by penetrating gunshot wounds of the neck, have been known to produce aphasia by interference with the blood-supply of the brain.

Digital compression of the common carotid artery is sometimes required, and is best effected by pressing the vessel with the thumb against the anterior tubercle of the transverse process of the sixth cervical vertebra (p. 208).

The upper part of the common carotid artery should be selected as the spot upon which to place a ligature, for the lower part is placed very deeply; moreover, on the left side, the internal jugular vein, in most cases, passes obliquely in front of it. The part of the vessel which is most favourable for the operation is that opposite the level of the cricoid cartilage.

Collateral Circulation.—After ligature of the common carotid, the collateral circulation can be perfectly established by the free communication which exists between the carotid arteries of opposite sides, both without and within the cranium, and by enlargement of the branches of the subclavian artery. The chief communications outside the skull take place between the superior and inferior thyroid arteries, and between the deep cervical and descending branch of the occipital; the vertebral takes the place of the internal carotid within the cranium.

Wounds of the common carotid should be treated by suture whenever possible, because, after ligature of the vessel, hemiplegia or other symptom of cerebral disturbance supervenes in about twenty-five per cent. of cases.

The External Carotid Artery

The **external carotid artery** (fig. 702) begins opposite the upper border of the thyroid cartilage, at the level of the disc between the third and fourth cervical vertebræ, and, taking a slightly curved course, passes upwards and forwards, and then inclines backwards to a point behind the neck of the mandible, where, in the substance of the parotid gland, it divides into the superficial temporal and maxillary (internal maxillary) arteries. It diminishes rapidly in size, owing to the number and large size of its branches. In the child, it is a little smaller than the internal carotid artery; but in the adult, the two vessels are of nearly equal size. At its origin, it is contained within the carotid triangle (p. 716), and lies superficial to and nearer the median plane than the internal carotid artery; higher up it is situated lateral to this artery.

Relations.—Within the carotid triangle the external carotid artery is covered by the skin, the superficial fascia, the loop between the cervical branch of the facial nerve and the anterior cutaneous nerve of the neck, the deep fascia, and the anterior margin of the Sternomastoid; it is crossed by the hypoglossal nerve and its vena comitans, by the lingual and common facial veins and sometimes by the superior thyroid vein. Leaving the carotid triangle it is crossed by the posterior belly of the Digastric and the Stylohyoid, and then ascends between the latter muscle and the posteromedial surface of the parotid gland. Finally, it enters the gland, where it lies deep to the facial nerve and the junction of the superficial temporal and maxillary veins. Medially, it is related to the wall of the pharynx, the superior laryngeal nerve, and the ascending pharyngeal artery. At a higher level the internal carotid artery is medial to it, but is separated from it by the styloid process, the Styloglossus and Stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve and a part of the parotid gland (fig. 705).

Applied Anatomy.—Ligature of the external carotid may be required in cases of wound of this vessel, or of its branches when these cannot be tied, and in some cases of pulsating tumours of the scalp or face. It is also done as a preliminary measure to excision of the maxilla or tongue. The seat of election for ligature is between the origins of its superior thyroid and lingual branches, just below the tip of the greater cornu of the hyoid bone.

Collateral Circulation.—The circulation is re-established by the free communication between most of the large branches of the artery (facial, lingual, superior thyroid, occipital) and the corresponding arteries of the opposite side, and by the anastomosis of its branches with those of the internal carotid artery, and of the occipital artery with branches of the subclavian, etc.

The Branches of the External Carotid Artery (figs. 702, 706)

The branches of the external carotid artery are:

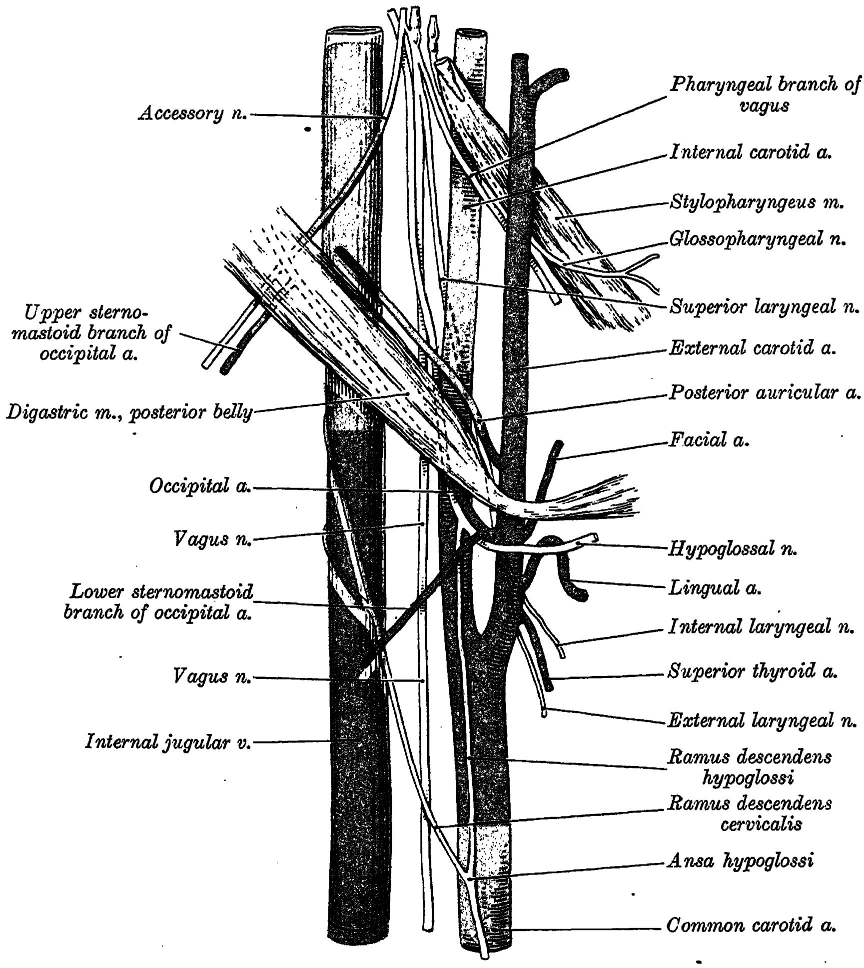
1. Superior thyroid.	4. Facial.	7. Superficial temporal.
2. Ascending pharyngeal.	5. Occipital.	8. Maxillary.
3. Lingual.	6. Posterior auricular.	

1. **The superior thyroid artery** (fig. 702) arises from the front of the external carotid artery just below the level of the greater cornu of the hyoid bone and,

divides into its terminal branches at the apex of the corresponding lobe of the thyroid gland.

Relations.—From its origin beneath the anterior border of the Sternomastoid it runs downwards and forwards in the carotid triangle along the lateral border of the Thyrohyoid, and is covered by the skin, Platysma and fasciæ; it then passes under cover of the Omohyoid, Sternohyoid and Sternothyroid.

FIG. 705.—A diagram showing the structures crossing the internal jugular vein and carotid arteries, and those intervening between the external and internal carotid arteries. Modified from a figure in R. B. Green's *Human Anatomy for Dental Students*, 1923.



o its medial side are the Constrictor pharyngis inferior and the external branch ᶠ the superior laryngeal nerve, but the nerve frequently lies on a more posterior plane.

Branches.—It distributes twigs to the adjacent muscles, and branches to the thyroid gland; it anastomoses with its fellow of the opposite side, and with the inferior thyroid arteries. The branches to the gland are generally two in number, an anterior and a posterior; the anterior branch follows the medial border of the upper pole of the lobe and supplies principally the anterior surface; it sends a branch across the upper border of the isthmus to anastomose with the corresponding artery of the opposite side; the posterior branch descends on the posterior border of the gland, supplying its medial and lateral surfaces, and anastomoses with the inferior thyroid artery. Sometimes a lateral branch is distributed to the lateral surface of the gland.

Besides the arteries distributed to the muscles and to the thyroid gland, the superior thyroid artery supplies the following branches:

Infrahyoid.	Superior laryngeal.
Sternomastoid.	Cricothyroid.

The **infrahyoid artery** is small and runs along the lower border of the hyoid bone deep to the Thyrohyoid, and anastomoses with the vessel of the opposite side.

The **sternomastoid branch** frequently arises from the external carotid artery; it runs downwards and laterally across the sheath of the common carotid artery, and enters the Sternomastoid.

The **superior laryngeal artery**, larger than either of the preceding, is frequently a separate branch of the external carotid artery; it accompanies the internal laryngeal nerve and passes deep to the Thyrohyoid; it pierces the lower part of the thyrohyoid membrane, and supplies the muscles, mucous membrane and glands of the larynx, anastomosing with the artery of the opposite side, and with the inferior laryngeal branch of the inferior thyroid artery.

The **cricothyroid branch** is small and runs transversely across the upper part of the cricothyroid ligament, communicating with the artery of the opposite side.

Applied Anatomy.—The superior thyroid artery, or one of its branches, is often divided in cases of cut throat, giving rise to considerable hæmorrhage. The superior thyroid is ligatured in cases of goitre where the removal of a lobe of the thyroid gland may present special dangers.

The position of the sternomastoid branch is of importance in connexion with the operation of ligature of the common carotid artery. It crosses and lies on the sheath of this vessel and may chance to be wounded in opening the sheath. The position of the cricothyroid branch should be remembered, as it may prove the source of troublesome hæmorrhage during the operation of laryngotomy.

2. The **ascending pharyngeal artery** (fig. 711), the smallest branch of the external carotid artery, is a long, slender vessel, deeply seated in the neck. It arises close to the origin of the external carotid artery, and ascends vertically between the internal carotid artery and the side of the pharynx to the under surface of the base of the skull, being crossed by the Styloglossus and the Stylopharyngeus and lying on the Longus capitis; it anastomoses freely with the ascending palatine branch of the facial (external maxillary) artery.

Its branches are:

Pharyngeal.	Inferior tympanic.	Meningeal.

The **pharyngeal branches** are three or four in number. Two of these descend to supply the Inferior and Middle constrictor muscles and the Stylopharyngeus, ramifying in their substance and in the underlying mucous membrane. A branch of variable size is distributed to the palate, and may take the place of the ascending palatine branch of the facial (external maxillary) artery; it runs downwards and forwards between the superior border of the Superior constrictor and the Levator palati, and accompanies the latter muscle to the soft palate; it gives branches to the tonsil, and supplies a twig to the pharyngotympanic (auditory) tube.

The **inferior tympanic artery** is a small branch which passes through the temporal bone, in the canaliculus for the tympanic branch of the glossopharyngeal nerve, to supply the medial wall of the tympanic cavity and anastomose with the other tympanic arteries.

The **meningeal branches** are several small vessels which supply the dura mater. One enters the cranium through the foramen lacerum; a second passes through the jugular foramen; and occasionally a third through the anterior condylar canal.

Numerous small vessels supply the Longi capitis et cervicis, the sympathetic trunk, the hypoglossal and vagus nerves, and the lymph glands; they anastomose with branches of the ascending cervical and vertebral arteries.

3. The **lingual artery** (fig. 711) arises from the anteromedial surface of the external carotid artery opposite to the tip of the greater cornu of the hyoid bone, and between the superior thyroid and facial arteries; it ends in the tongue. Running obliquely upwards and medially at first, it then curves downwards and forwards to the greater cornu of the hyoid bone, forming a loop which is characteristic of the vessel; it passes deep to the posterior border of the Hyoglossus, runs horizontally forwards under cover of that muscle, and finally, ascending almost perpendicularly, courses forwards on the under surface of the tongue as far as the tip.

Course and relations.—The *first part* of the lingual artery lies in the carotid triangle ; superficial to it are the skin, fascia and Platysma ; deep to it, the Middle constrictor muscle. It runs upwards and medially for a short distance, and then descends to the level of the hyoid bone, forming a loop, which is crossed by the hypoglossal nerve. The *second part* of the artery courses along the upper border of the hyoid bone, deep to the Hyoglossus, the tendon of the Digastric or its fascial retinaculum, the Stylohyoid, the lower part of the submandibular (submaxillary) gland and the posterior part of the Mylohyoid ; the Hyoglossus separates the artery from the hypoglossal nerve and its vena comitans ; in this part of its course it lies on the Middle constrictor muscle and crosses the stylohyoid ligament. The *third part* of the artery is named the *arteria profunda linguae.* It bends sharply upwards near the anterior border of the Hyoglossus, and then runs forwards on the inferior surface of the tongue near the frenulum, accompanied by the lingual nerve. Medially, it is related to the Genioglossus ; laterally, to the Longitudinalis linguæ inferior ; below, to the mucous membrane of the tongue. At the tip of the tongue it anastomoses with the lingual artery of the opposite side.

The branches of the lingual artery are :

Suprahyoid.	Sublingual.
Rami dorsales linguæ.	Arteria profunda linguæ.

The **suprahyoid artery** is very small ; it runs along the upper border of the hyoid bone, and anastomoses with its fellow of the opposite side.

The **rami dorsales linguæ** consist usually of two or three small branches ; they arise under cover of the Hyoglossus, ascend to the posterior part of the dorsum of the tongue, and supply the mucous membrane of the tongue, the palatoglossal arch, the tonsil, soft palate and epiglottis ; they anastomose with the vessels of the opposite side.

The **sublingual branch** arises at the anterior margin of the Hyoglossus, and runs forward between the Genioglossus and Mylohyoid to the sublingual gland. It supplies the gland and gives branches to the Mylohyoid and neighbouring muscles, and to the mucous membrane of the mouth and gums. One branch runs behind the alveolar part of the mandible in the substance of the gum to anastomose with a similar artery from the other side ; another pierces the Mylohyoid and anastomoses with the submental branch of the facial (external maxillary) artery.

The **arteria profunda linguæ**—the terminal portion of the lingual artery—is described above.

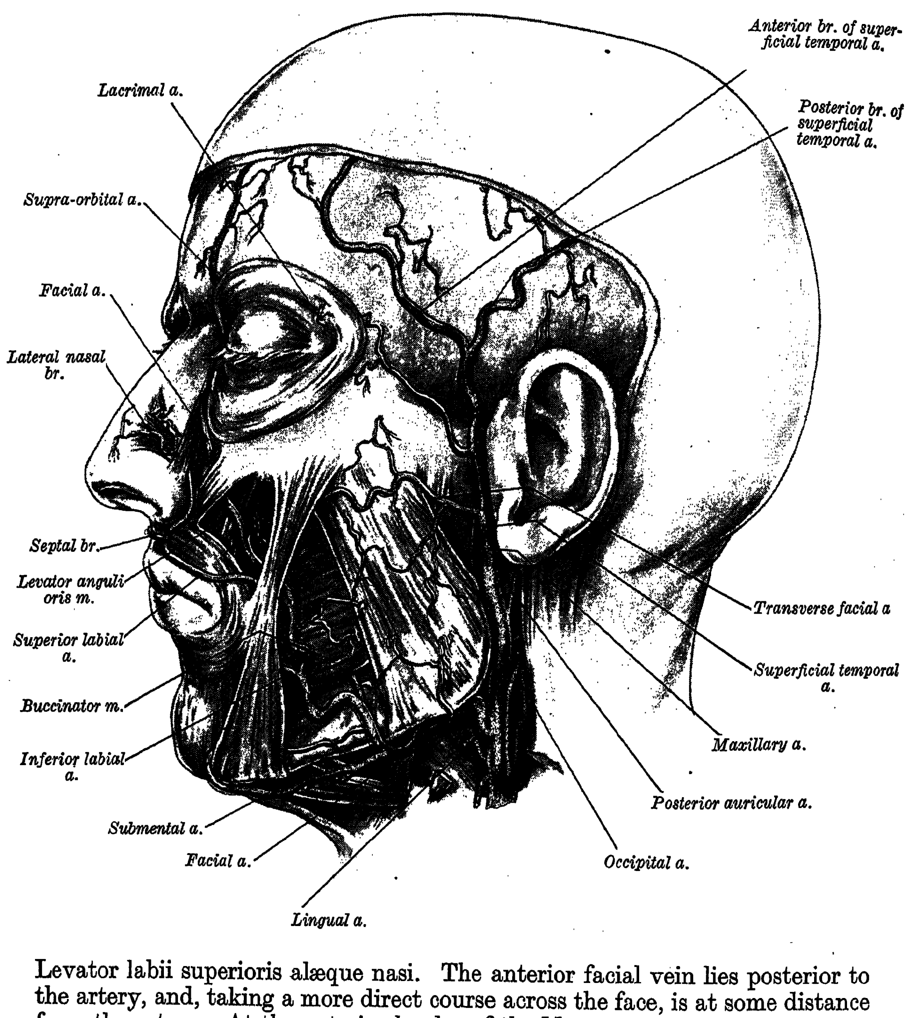
Applied Anatomy.—The lingual artery is not infrequently divided near its origin in cases of cut throat ; while severe hæmorrhage, which cannot be restrained by ordinary means, may ensue from a wound, or deep ulcer, of the tongue. In the former case, the primary wound may be enlarged if necessary, and the bleeding vessel secured ; in the latter, it has been suggested that the lingual artery should be tied near its origin.

4. The **facial artery** (external maxillary artery) (fig. 706) arises from the front of the external carotid artery in the carotid triangle a little higher than the lingual artery, and immediately above the greater cornu of the hyoid bone. Sheltered by the ramus of the mandible, it arches upwards and enters a groove in the posterior border of the submandibular (submaxillary) gland. It next turns downwards and forwards between the gland and the Medial pterygoid muscle, and, reaching the lower border of the mandible, ascends over it at the anterior edge of the Masseter, and enters the face. On the face it passes forwards and upwards across the cheek to the angle of the mouth, then ascends along the side of the nose, and ends at the medial palpebral commissure, where it supplies branches to the lacrimal sac, and anastomoses with the dorsal nasal branch of the ophthalmic artery. The facial artery is remarkably tortuous : in the neck to accommodate itself to the movements of the pharynx during deglutition, and on the face to accommodate itself to the movements of the mandible, lips and cheeks.

Relations.—*In the neck,* at its origin, the artery is superficial, being placed under cover of the skin, Platysma, and fasciæ, and is frequently crossed by the hypoglossal nerve. It runs upwards and forwards, deep to the Digastric and Stylohyoid and to the posterior part of the submandibular (submaxillary) gland. At first on the surface of the Middle constrictor of the pharynx, it may reach as high as the lateral surface of the Styloglossus, and it is then separated from the tonsil only by that muscle and the lingual fibres of origin of the Superior

constrictor. Next, it descends to the lower border of the mandible, lying in a groove on the lateral aspect of the submandibular (submaxillary) gland. *In the face*, where it passes over the body of the mandible, it is comparatively superficial, lying immediately beneath the Platysma. In its course over the face, it is under cover of the skin, the fat of the cheek, and, near the angle of the mouth, the Platysma, Risorius and Zygomaticus major. It rests on the Buccinator and Levator anguli oris (Caninus), and passes either over or through the Levator labii superioris. Its terminal part is embedded in the fibres of the

FIG. 706.—The arteries of the left side of the face.



Levator labii superioris alæque nasi. The anterior facial vein lies posterior to the artery, and, taking a more direct course across the face, is at some distance from the artery. At the anterior border of the Masseter the two vessels are in contact; in the neck the vein is superficial to the artery. The branches of the facial nerve cross the artery from behind forwards.

The branches of the facial artery may be divided into two sets: those given off in the neck (cervical) and those on the face (facial).

Cervical branches.	*Facial branches.*
Ascending palatine.	Inferior labial.
Tonsillar.	Superior labial.
Glandular.	Lateral nasal.
Submental.	

The **ascending palatine artery** (fig. 711) arises close to the origin of the facial artery and passes up between the Styloglossus and Stylopharyngeus to the side of the pharynx,

along which it is continued between the Superior constrictor and the Medial pterygoid muscles towards the base of the skull. Near the Levator palati it divides into two branches: one follows the course of this muscle, and, winding over the upper border of the Superior constrictor, supplies the soft palate and the palatine glands, anastomosing with its fellow of the opposite side and with the greater (descending) palatine branch of the maxillary (internal maxillary) artery; the other pierces the Superior constrictor and supplies the tonsil and the pharyngotympanic (auditory tube), anastomosing with the tonsillar and ascending pharyngeal arteries.

The **tonsillar artery** (fig. 711) is the principal artery to the tonsil. Sometimes derived from the ascending palatine artery, it ascends between the Medial pterygoid and Styloglossus, and, at the upper border of the latter muscle, it perforates the Superior constrictor and ramifies in the tonsil and the root of the tongue.

The **glandular branches**, three or four large vessels, supply the submandibular (submaxillary) salivary gland and lymph glands, the neighbouring muscles and the skin.

The **submental artery**, the largest cervical branch of the facial artery, springs from that artery just as it quits the submandibular gland: it runs forwards upon the Mylohyoid (fig. 706), below the body of the mandible, and deep to the anterior belly of the Digastric. It supplies the surrounding muscles, and anastomoses with the sublingual branch of the lingual artery and with the mylohyoid branch of the inferior dental artery; at the chin it turns upwards over the inferior border of the mandible and divides into a superficial and a deep branch. The superficial branch passes between the skin and the Depressor labii inferioris, and anastomoses with the inferior labial artery; the deep branch runs between the muscle and the bone, supplies the lip, and anastomoses with the inferior labial and mental arteries.

The **inferior labial artery** (fig. 706) arises near the angle of the mouth; it passes upwards and forwards under cover of the Depressor anguli oris (Triangularis), and, penetrating the Orbicularis oris, runs in a tortuous course near the edge of the lower lip between this muscle and the mucous membrane. It supplies the glands, mucous membrane and muscles of the lower lip; and anastomoses with the artery of the opposite side, and with the mental branch of the inferior dental artery.

The **superior labial artery** (fig. 706) is larger and more tortuous than the inferior. It follows a similar course near the edge of the upper lip, lying between the mucous membrane and the Orbicularis oris, and anastomoses with the artery of the opposite side. It supplies the upper lip, and gives off a *septal branch*, which ramifies on the lower and front part of the nasal septum, and an *alar branch*, which supplies the ala of the nose.

The **lateral nasal branch** (fig. 706) is derived from the facial artery as that vessel ascends along the side of the nose. It supplies the ala and dorsum of the nose, anastomosing with its fellow, with the septal and alar branches of the superior labial artery, with the dorsal nasal branch of the ophthalmic artery, and with the infra-orbital branch of the maxillary (internal maxillary) artery.

The anastomoses of the facial artery are very numerous, not only with the branches of the vessel of the opposite side, but, *in the neck*, with the sublingual branch of the lingual, with the ascending pharyngeal and with the palatine branch of the maxillary; *on the face*, with the mental branch of the inferior dental, the transverse facial branch of the superficial temporal, the infra-orbital branch of the maxillary and the dorsal nasal branch of the ophthalmic.

Peculiarities.—The facial artery not infrequently arises in common with the lingual artery. It varies in size, and in the extent to which it supplies the face; it occasionally ends at the submental, and not infrequently extends only as high as the angle of the mouth or nose. The deficiency is then compensated for by enlargement of one of the neighbouring arteries.

Applied Anatomy.—The passage of the facial artery over the body of the mandible would appear to afford a favourable position for the application of pressure in cases of hæmorrhage from the lips; but such application is useless, except for a very short time, on account of the free communication of the artery with its fellow, and with numerous branches from different sources. In a wound involving the lip, it is better to seize the part between the fingers, and evert it, when the bleeding vessel may be at once secured with pressure-forceps. The student should observe that the terminal part of the facial artery ascends on the nasal side of the lacrimal sac; in operating for fistula lacrimalis, the sac should always be opened on its lateral side, in order to avoid this vessel.

The facial artery is separated from the lower and hinder part of the tonsil by the Superior constrictor and Styloglossus muscles, and may be wounded in operations in that region.

The free anastomosis of the branches of the facial artery contributes to the success of plastic operations on the face.

5. The **occipital artery** (fig. 707) arises from the posterior part of the external carotid artery, opposite to the facial artery; and running at first on the deep

surface of the posterior belly of the Digastric, ends in the posterior part of the scalp.

Relations.—At its origin, it lies in the carotid triangle, and is crossed by the hypoglossal nerve, which winds round it from behind forwards. The artery passes backwards and upwards deep to the lower border of the posterior belly of the Digastric, crossing in its course the internal carotid artery, the internal jugular vein, and the hypoglossal, vagus and accessory nerves. Reaching the interval between the transverse process of the atlas and the mastoid process of the temporal bone, it comes into contact with the lateral border of the Rectus capitis lateralis. It then runs in the occipital groove on the temporal bone, and here is covered by the Sternomastoid, Splenius capitis, Longissimus capitis and Digastric, and lies successively on the Rectus capitis lateralis, Obliquus superior and Semispinalis capitis. Finally, it turns upwards and pierces the fascia connecting the cranial attachment of the Trapezius with the Sternomastoid, and ascends in a tortuous course in the superficial fascia of the scalp, where it divides into numerous branches. The terminal portion of the occipital artery is accompanied by the greater occipital nerve.

The branches of the occipital artery are:

Sternomastoid.	Auricular.	Meningeal.
Mastoid.	Muscular.	Occipital.
	Descending.	

The **sternomastoid branches** are usually two in number. The *lower branch* generally arises from the beginning of the occipital artery, but sometimes springs directly from the external carotid artery. It passes downwards and backwards over the hypoglossal nerve and the internal jugular vein, and enters the substance of the Sternomastoid; it anastomoses with the sternomastoid branch of the superior thyroid artery. The *upper branch* arises from the occipital artery as it crosses the accessory nerve, and runs downwards and backwards superficial to the internal jugular vein. It enters the deep surface of the Sternomastoid in company with the accessory nerve.

The **mastoid branch**, small in size and sometimes absent, enters the cranial cavity through the mastoid foramen; it gives branches to the mastoid air-cells and the dura mater, and anastomoses with the middle meningeal artery.

The **auricular branch** supplies the back of the concha and anastomoses with the posterior auricular artery.

Muscular branches are supplied to the Digastric, Stylohyoid, Splenius and Longissimus capitis.

The **descending branch** (fig. 707) arises from the occipital artery as the latter lies on the Obliquus superior, and divides into a superficial and a deep branch. The superficial branch passes deep to the Splenius, and anastomoses with the superficial branch of the transverse cervical artery; the deep branch descends between the Semispinales capitis et cervicis, and anastomoses with the vertebral artery, and with the deep cervical artery, a branch of the costocervical trunk (fig. 711). The anastomosis between these vessels assists in establishing the collateral circulation after ligature of the common carotid or subclavian artery.

The **meningeal branches** enter the skull through the jugular foramen and posterior condylar canal, to supply the dura mater in the posterior fossa.

The **occipital branches**, which are the terminal branches, are distributed to the scalp, and reach as high as the vertex of the skull; they are very tortuous, and lie between the skin and the occipital belly of Occipitofrontalis, anastomosing with the artery of the opposite side and with the posterior auricular and temporal arteries, and supplying the occipital belly of Occipitofrontalis, the skin and the pericranium. One of the terminal branches may give off a meningeal twig, which passes through the parietal foramen.

6. The **posterior auricular artery** (fig. 706) is small and arises from the posterior surface of the external carotid artery immediately above the Digastric and Stylohyoid. It ascends, under cover of the parotid gland, on the styloid process of the temporal bone, to the groove between the cartilage of the auricle and the mastoid process, where it divides into auricular and occipital branches.

In addition to supplying small branches to the Digastric, Stylohyoid, Sternomastoid, and parotid gland, this vessel gives off the three following branches:

Stylomastoid.	Auricular.	Occipital.

The **stylomastoid artery** enters the stylomastoid foramen, and supplies the tympanic cavity, the tympanic antrum, the mastoid air-cells and the semicircular canals. In the

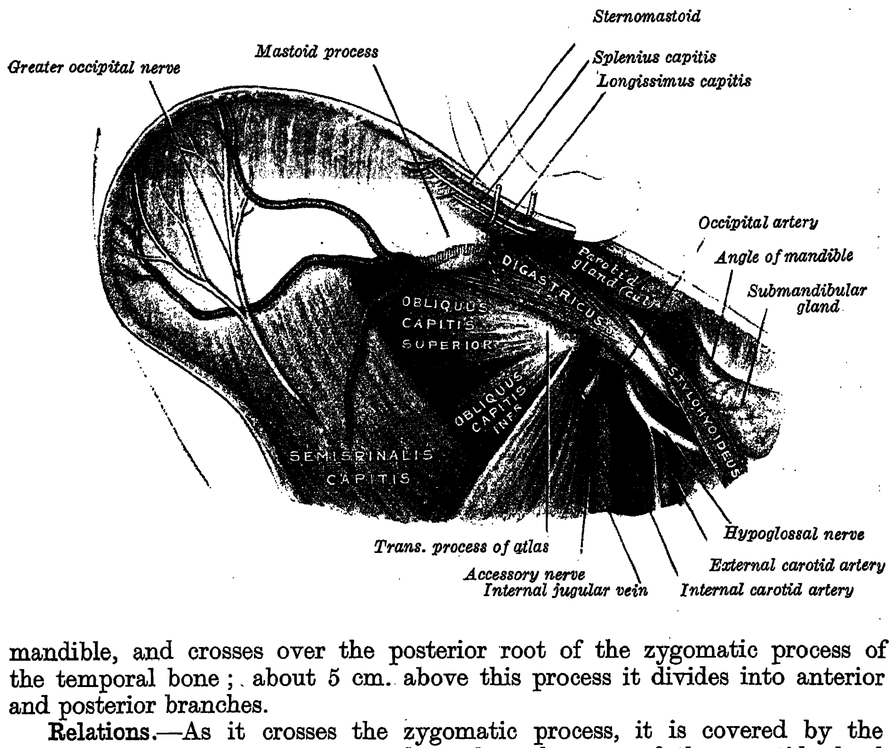
young subject a branch from this vessel (termed the *posterior tympanic artery*) forms, with the anterior tympanic artery from the maxillary (internal maxillary), a vascular circle which surrounds, and supplies small vessels to, the deep surface of the tympanic membrane. It anastomoses with the superficial petrosal branch of the middle meningeal artery.

The **auricular branch** ascends under cover of the Auricularis posterior, and ramifies on the cranial surface of the auricle; some of its branches pierce the auricle, and others curve round its margin to supply its lateral surface. It anastomoses with the posterior and auricular branches of the superficial temporal artery.

The **occipital branch** passes laterally across the front of the mastoid process and then backwards over the Sternomastoid to the occipital belly of the Occipitofrontalis muscle and to the scalp above and behind the ear; it anastomoses with the occipital artery.

7. The **superficial temporal artery** (fig. 702), the smaller terminal branch of the external carotid artery, begins in the parotid gland, behind the neck of the

FIG. 707.—A drawing of a dissection to show the course of the occipital artery.



mandible, and crosses over the posterior root of the zygomatic process of the temporal bone; about 5 cm. above this process it divides into anterior and posterior branches.

Relations.—As it crosses the zygomatic process, it is covered by the Auricularis anterior; it is crossed in the substance of the parotid gland by the temporal and zygomatic branches of the facial nerve, and is accompanied in the scalp by the auriculotemporal nerve, which lies immediately behind it.

It supplies some twigs to the parotid gland, the mandibular joint and the Masseter, and gives off the following branches:

Transverse facial.	Zygomatic.	Anterior.
Auricular.	Middle temporal.	Posterior.

The **transverse facial artery** (fig. 706) arises from the superficial temporal artery before that vessel quits the parotid gland; it runs forwards through the substance of the gland, passes across the Masseter between the parotid duct and the zygomatic arch, accompanied by one or two branches of the facial nerve. It divides into numerous branches, which supply the parotid gland and duct, the Masseter, and the skin, and anastomose with the facial (external maxillary), masseteric, buccal, and infra-orbital arteries.

The **auricular branches** are distributed to the lobule and anterior portion of the auricle, and to the external auditory meatus; they anastomose with the posterior auricular artery.

The **zygomatic artery**, sometimes a branch of the middle temporal artery, runs along the upper border of the zygomatic arch between the two layers of the temporal fascia to the lateral angle of the orbit. It supplies branches to the Orbicularis oculi, and anastomoses with the lacrimal and palpebral branches of the ophthalmic artery.

The **middle temporal artery** arises immediately above the zygomatic arch, and, perforating the temporal fascia, gives branches to the Temporalis; it anastomoses with the deep temporal branches of the maxillary artery.

The **anterior (frontal) branch** runs tortuously upwards and forwards towards the frontal eminence; it supplies the muscles, skin and pericranium in this region, and anastomoses with its fellow of the opposite side, and with the supra-orbital and supratrochlear (frontal) arteries.

The **posterior (parietal) branch**, larger than the anterior, curves upwards and backwards on the side of the head, lying superficial to the temporal fascia, and anastomosing with its fellow of the opposite side, and with the posterior auricular and occipital arteries.

Applied Anatomy.—As the superficial temporal artery crosses the zygomatic process, it lies beneath the skin and fascia, and its pulsations may be readily felt during the administration of an anæsthetic, or in circumstances where the radial pulse is not available; it may be compressed easily against the bone in order to check bleeding from the temporal region of the scalp. When a flap is raised from this part of the head, for trephining, the incision should be shaped like a horseshoe, with its convexity upwards, so that the flap shall contain the superficial temporal artery, which ensures a sufficient supply of blood.

8. The **maxillary artery** (internal maxillary artery) (fig. 708), the larger terminal branch of the external carotid artery, arises behind the neck of the mandible and is at first imbedded in the parotid gland; it passes forwards between the neck of the mandible and the sphenomandibular ligament, and then running either superficial or deep to the lower head of the Lateral pterygoid, enters the pterygopalatine fossa between the two heads of that muscle. It may be divided into mandibular, pterygoid and pterygopalatine portions.

The *first* or *mandibular portion* passes horizontally forwards, between the neck of the mandible and the sphenomandibular ligament, where it lies parallel with and a little below the auriculotemporal nerve; it crosses the inferior dental nerve, and runs along the lower border of the Lateral pterygoid.

The *second* or *pterygoid portion* runs obliquely forwards and upwards under cover of the Temporal muscle, and superficial to the lower head of the Lateral pterygoid muscle; very frequently it lies deep to the latter, between it and the branches of the mandibular nerve, and in this case, before entering on the third part of its course, it often forms a wide loop which projects laterally between the two heads of the Lateral pterygoid muscle.

The *third* or *pterygopalatine portion* passes between the upper and lower heads of the Lateral pterygoid muscle, and through the pterygomaxillary fissure into the pterygopalatine fossa, where it lies in front of the sphenopalatine ganglion.

The branches of the vessel may be divided into three groups, corresponding with its three portions.

The Branches of the First or Mandibular Portion of the Maxillary Artery (fig. 708)

Deep auricular.	Middle meningeal.
Anterior tympanic.	Accessory meningeal.

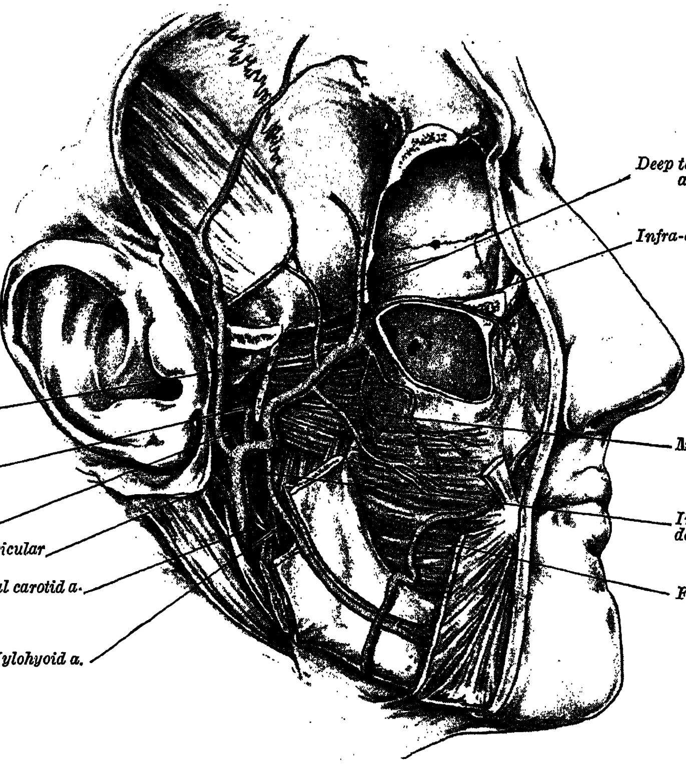
Inferior dental.

The **deep auricular artery**, a small branch, often arises in common with the anterior tympanic. It ascends in the substance of the parotid gland, behind the mandibular joint, pierces the cartilaginous or bony wall of the external auditory meatus, and supplies its cuticular lining and the outer surface of the tympanic membrane; it gives a branch to the mandibular joint.

The **anterior tympanic artery**, a small branch, ascends behind the mandibular joint, and enters the tympanic cavity through the squamotympanic fissure; it ramifies upon the tympanic membrane, and forms a vascular circle around it with the posterior tympanic branch of the stylomastoid artery; it anastomoses with the artery of the pterygoid canal and with the caroticotympanic branch from the internal carotid artery.

The **middle meningeal artery** is the largest of the meningeal arteries. It ascends between the sphenomandibular ligament and the Lateral pterygoid muscle, and between the two roots of the auriculotemporal nerve, and may lie on the lateral surface of the Tensor palati just before it enters the cranial cavity through the foramen spinosum of the sphenoid bone; it then runs forwards and laterally for a variable distance in a groove on the anterior part of the squamous part of the temporal bone, and divides into an anterior and a posterior branch. The *anterior branch*, the larger, crosses the greater wing of the sphenoid bone, reaches the groove, or canal, in the anterior inferior angle of the parietal bone, and then divides into branches which spread out between the dura mater and internal surface of the cranium, some passing upwards as far as the vertex, and others backwards to the occipital region. One branch

FIG. 708 —The right maxillary (internal maxillary) artery.



An extensive dissection has been carried out, involving the removal of the parotid gland, the zygomatic arch, part of the ramus of the mandible, the lateral walls of the orbit and maxillary sinus and the orbital contents.

runs upwards, grooving the parietal bone about 1·5 cm. behind the coronal suture. It corresponds, in a general way, to the line of the precentral sulcus of the brain. The *posterior branch* curves backwards on the squamous part of the temporal bone, and, reaching the lower border of the parietal bone some distance in front of its posterior inferior angle, divides into branches which supply the posterior part of the dura mater and cranium. The branches of the middle meningeal artery anastomose with the arteries of the opposite side, and with the anterior and posterior meningeal arteries.

The middle meningeal artery gives off the following branches within the cranial cavity: 1. Numerous small *ganglionic branches* supply the ganglion and the roots of the trigeminal nerve. 2. A *superficial petrosal branch* enters the hiatus for the greater superficial petrosal nerve, gives twigs to the facial nerve and the tympanic cavity, and anastomoses with the stylomastoid branch of the posterior auricular artery. 3. *A superior tympanic artery* runs in the canal for the Tensor tympani, and supplies this muscle and the lining membrane of

the canal. 4. *Temporal branches* pass through minute foramina in the greater wing of the sphenoid, and anastomose in the temporal fossa with the deep temporal arteries. 5. An *orbital branch* (p. 148) runs forwards and enters the orbit through the lateral part of the superior orbital fissure. It anastomoses with a recurrent meningeal branch of the lacrimal artery, and an enlargement of this anastomosis explains the occasional origin of the lacrimal from the middle meningeal artery.

Applied Anatomy.—The middle meningeal artery is of considerable surgical importance, as it may be torn in fractures of the temporal region of the skull, or, indeed, by injuries causing separation of the dura mater from the bone without fracture. The injury may be followed by considerable hæmorrhage between the bone and dura mater, which produces symptoms of compression of the brain, and requires trephining for its relief. As the compression implicates the motor region of the cortex, paralysis on the opposite side of the body forms the prominent symptom of the lesion. The anterior branch of this artery lies in a groove or a bony canal on the anterior inferior angle of the parietal bone at a point 4 cm. behind the zygomatic process of the frontal bone, and 4·5 cm. above the zygomatic arch. From this point it passes upwards and slightly backwards to the sagittal suture, lying about 1·25 to 2 cm. behind the coronal suture.

The **accessory meningeal branch** may arise from the maxillary artery or from the middle meningeal artery. It enters the cranial cavity through the foramen ovale, and supplies branches to the trigeminal ganglion and the dura mater.

The **inferior dental artery** descends posterior to the inferior dental nerve to the mandibular foramen on the medial surface of the ramus of the mandible. In this part of its course the artery lies between the bone on the lateral side, and the sphenomandibular ligament on the medial side. Before it enters the mandibular foramen, it gives off a *mylohyoid* branch, which pierces the sphenomandibular ligament, and descends with the mylohyoid nerve in the mylohyoid groove on the ramus of the mandible; it ramifies on the superficial surface of the Mylohyoid muscle and anastomoses with the submental branch of the facial (external maxillary) artery. The inferior dental artery then runs in the mandibular canal, accompanied by the inferior dental nerve, and, opposite the first premolar tooth, divides into two branches, incisor and mental. The *incisor* branch is continued forwards below the incisor teeth as far as the median plane, where it anastomoses with the artery of the opposite side. Within the canal the inferior dental artery and its incisor branch give off a few twigs to the mandible, and a series of branches which correspond in number to the roots of the teeth; these enter the minute apertures at the extremities of the roots, and supply the pulp of the teeth. The *mental* branch escapes at the mental foramen, supplies the chin, and anastomoses with the submental and inferior labial arteries. Near its origin the inferior dental artery gives off a *lingual* branch, which descends with the lingual nerve and supplies the mucous membrane of the mouth.

The Branches of the Second or Pterygoid Portion of the Maxillary Artery (fig. 708)

Deep temporal. Pterygoid. Masseteric. Buccal.

The **deep temporal branches**, an anterior and a posterior, ascend between the Temporalis and the pericranium; they supply the muscle, and anastomose with the middle temporal artery; the anterior communicates with the lacrimal artery by means of small branches which perforate the zygomatic bone and greater wing of the sphenoid bone.

The **pterygoid branches**, irregular in their number and origin, supply the Pterygoid muscles.

The **masseteric artery** is small and passes with the corresponding nerve behind the tendon of the Temporalis, and through the mandibular notch to the deep surface of the Masseter. In the substance of that muscle it anastomoses with the masseteric branches of the facial (external maxillary) and with branches of the transverse facial artery.

The **buccal artery** is small and runs obliquely forwards with the buccal nerve, between the Medial pterygoid and the insertion of the Temporal muscle, to the outer surface of the Buccinator, to which it is distributed, anastomosing with branches of the facial and infra-orbital arteries.

The Branches of the Third or Pterygopalatine Portion of the Maxillary Artery.

Posterior superior dental.	Pharyngeal.
Infra-orbital.	Artery of the pterygoid canal.
Greater palatine.	Sphenopalatine.

The **posterior superior dental artery** (posterior superior alveolar artery) is given off from the maxillary artery as that vessel enters the pterygopalatine fossa. Descending upon the posterior surface of the maxilla, it divides into branches, some of which enter the dental canals, and supply the molar and premolar teeth and the lining of the maxillary sinus, while others are continued forwards on the alveolar process to supply the gums.

The **infra-orbital artery** often arises in conjunction with the posterior superior dental artery. It enters the orbital cavity through the posterior part of the inferior orbital fissure, runs along the infra-orbital groove and canal with the infra-orbital nerve, and emerges with the nerve on the face through the infra-orbital foramen, deep to the Levator labii superioris. Whilst in the canal, it gives off (*a*) *orbital* branches, which assist in supplying the Rectus inferior, the Obliquus inferior and the lacrimal sac, and (*b*) *anterior superior dental* branches, which descend through the anterior dental canals to supply the upper incisor and canine teeth, and the mucous membrane of the maxillary sinus. On the face, some branches ascend to the medial angle of the eye and the lacrimal sac, anastomosing with the terminal branches of the facial (external maxillary) artery; others run towards the nose, anastomosing with the dorsal nasal branch of the ophthalmic artery; and others descend between the Levator labii superioris and the Levator anguli oris (Caninus), and anastomose with the facial, transverse facial and buccal arteries.

The remaining branches of the maxillary artery arise from that portion of the artery which is contained in the pterygopalatine fossa.

The **greater palatine artery** (descending palatine artery) descends through the greater palatine (pterygopalatine) canal with the greater palatine nerve from the sphenopalatine ganglion, and gives off two or three *lesser palatine arteries*, which are transmitted through the lesser palatine canals to supply the soft palate and tonsil, and to anastomose with the ascending palatine artery. The greater palatine artery emerges on the oral surface of the palate through the greater palatine foramen, runs forwards, in a groove near the alveolar border of the hard palate, to the incisive canal; its terminal part passes upwards through this canal, and anastomoses with a branch of the sphenopalatine artery. Branches are distributed to the gums, the palatine glands and the mucous membrane of the roof of the mouth.

The **pharyngeal branch** is very small; it runs backwards through the pharyngeal canal with the pharyngeal branch of the sphenopalatine ganglion, and is distributed to the roof of the nose and pharynx, to the sphenoidal air-sinus and the pharyngotympanic tube.

The **artery of the pterygoid canal,** frequently a branch of the greater (descending) palatine artery, passes backwards along the pterygoid canal with the corresponding nerve. It is distributed to the upper part of the pharynx and to the pharyngotympanic tube, and sends into the tympanic cavity a small branch which anastomoses with the other tympanic arteries.

The pharyngeal branch is medial, and the artery of the pterygoid canal lateral, to the sphenopalatine ganglion, while the trunk of the maxillary artery is in front of it.

The **sphenopalatine artery** is really the terminal part of the maxillary artery; it passes through the sphenopalatine foramen into the cavity of the nose at the posterior part of the superior meatus. Here it gives off its *posterior lateral nasal* branches, which ramify over the conchæ and meatuses, anastomose with the ethmoidal arteries and the nasal branches of the greater palatine artery, and assist in supplying the frontal, maxillary, ethmoidal and sphenoidal sinuses. Crossing the anterior part of the under surface of the sphenoid bone, the sphenopalatine artery ends on the nasal septum as the *posterior septal* branches, which anastomose with the ethmoidal arteries; one branch descends in a groove on the vomer to the incisive canal and anastomoses with the terminal ascending branch of the greater palatine artery, and with the septal branch of the superior labial artery.

The Triangles of the Neck (fig. 709)

The side of the neck presents a somewhat quadrilateral outline, limited above by the base of the mandible, and a line drawn from the angle of the mandible to the mastoid process ; below, by the upper border of the clavicle ; in front, by the anterior median line of the neck ; behind, by the anterior margin of the Trapezius. This space is subdivided by the Sternomastoid muscle, which passes obliquely across the neck, from the sternum and clavicle below, to the mastoid process and occipital bone above. The area in front of this muscle is called the *anterior triangle* of the neck ; that behind it, the *posterior triangle.*

The Anterior Triangle of the Neck (figs. 709, 710)

The **anterior triangle** of the neck is bounded anteriorly by the anterior median line of the neck, posteriorly, by the anterior margin of the Sternomastoid; its base, directed upwards, is formed by the base of the mandible, and a line from the angle of the mandible to the mastoid process : its apex is below, at the sternum. This triangle may be subdivided into muscular, carotid, digastric and submental triangles.

The **muscular triangle** is bounded, in front, by the median line of the neck from the hyoid bone to the sternum ; behind and below, by the anterior margin of the Sternomastoid ; behind and above, by the superior belly of the Omohyoid. It is covered by the skin, superficial fascia, Platysma and deep fascia, ramifying in which are some of the branches of the anterior cutaneous cervical nerve (nervus cutaneus colli). The floor of the triangle is formed by the Sternohyoid, the Sternothyroid and the superior belly of the Omohyoid.

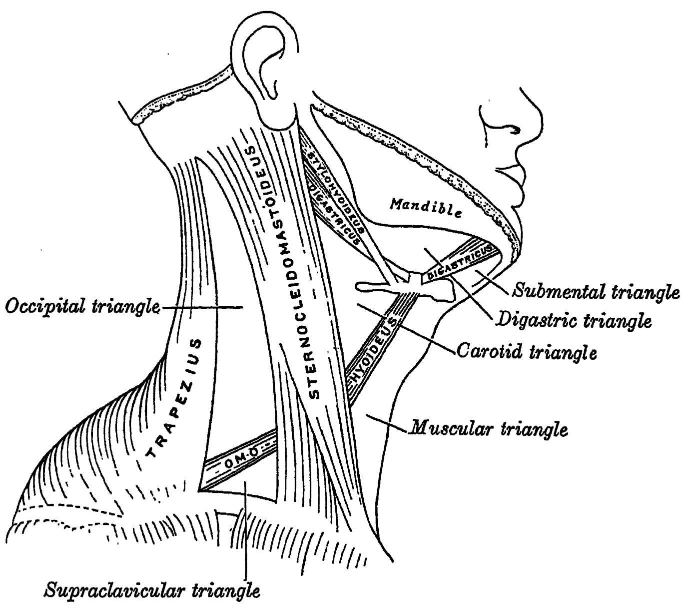
The **carotid triangle** is limited, behind, by the Sternomastoid ; in front and below, by the superior belly of the Omohyoid ; and above, by the Stylohyoid and the posterior belly of the Digastric. It is covered by the skin, superficial fascia, Platysma and deep fascia, ramifying in which are branches of the facial and the cutaneous cervical nerves. Its floor is formed by parts of the Thyrohyoid, Hyoglossus, and the Inferior and Middle constrictor muscles of the pharynx. When this space is dissected it is seen to contain the upper part of the common carotid artery, which divides opposite the superior border of the thyroid cartilage into the external and internal carotid arteries. These vessels are overlapped by the anterior margin of the Sternomastoid. The external and internal carotid arteries lie side by side, the external being the more anterior. The following branches of the external carotid artery are also encountered : the superior thyroid, running forwards and downwards ; the lingual, forwards with an upward loop ; the facial (external maxillary), forwards and upwards ; the occipital, upwards and backwards ; and the ascending pharyngeal, directly upwards on the medial side of the internal carotid. The veins encountered are : the internal jugular, which lies on the lateral side of the common and internal carotid arteries ; and veins corresponding to the above-mentioned branches of the external carotid artery—viz. the superior thyroid, the lingual, common facial, ascending pharyngeal, and sometimes the occipital—all of which end in the internal jugular vein. The hypoglossal nerve crosses both the internal and external carotid arteries, curving round the origin of the lower Sternomastoid branch of the occipital artery ; in this position it gives off its descending ramus, which runs down in the anterior wall of the carotid sheath. The vagus nerve lies within the sheath, between the common carotid artery and the internal jugular vein, and behind both ; behind the sheath is the sympathetic trunk. The accessory nerve appears at the lower border of the posterior belly of the Digastric, and descends for a short distance on the lateral side of the vessels before it pierces the deep surface of the Sternomastoid. On the medial side of the external carotid artery, below the hyoid bone, is the internal laryngeal nerve ; and, still more inferiorly, the external

laryngeal nerve. The upper portion of the larynx and lower portion of the pharynx are also found in the anterior part of this triangle.

It should be noted that many of the structures which have been included in the above description of the contents of the carotid triangle actually lie under cover of the Sternomastoid and can be seen only when the anterior border of the muscle is retracted.

The **digastric triangle** is bounded, above, by the base of the mandible and a line drawn from its angle to the mastoid process ; below, by the posterior belly of the Digastric and the Stylohyoid ; in front, by the anterior belly of the Digastric. It is covered by the skin, superficial fascia, Platysma and deep fascia, ramifying in which are branches of the facial and anterior cutaneous cervical nerves. Its floor is formed by the Mylohyoid and Hyoglossus muscles. It is divided into an anterior and a posterior part by the stylomandibular ligament. The anterior part contains the submandibular (submaxillary) gland, superficial

FIG. 709.—The triangles of the neck.



to which is the anterior facial vein, while deep to it is the facial artery, which crosses the lower border of the mandible at the anterior edge of the Masseter ; on the surface of the Mylohyoid are the submental artery and the mylohyoid artery and nerve. The posterior part of this triangle contains the lower part of the parotid gland ; the external carotid artery ascends between the gland and the Stylohyoid muscle and then in the substance of the gland ; in this triangle the external carotid artery lies superficial to the internal carotid and crosses lateral to it ; more deeply placed, and separated from the external carotid artery by the Styloglossus, the Stylopharnygeus and the glosso-pharnygeal nerve, are the internal carotid artery, the internal jugular vein and the vagus nerve.

The **submental triangle** is limited on each side by the anterior belly of the Digastric ; its apex is at the mandible ; its base is formed by the body of the hyoid bone, and its floor by the Mylohyoid muscles. It contains one or two lymph glands and some small veins ; the latter unite to form the anterior jugular vein.

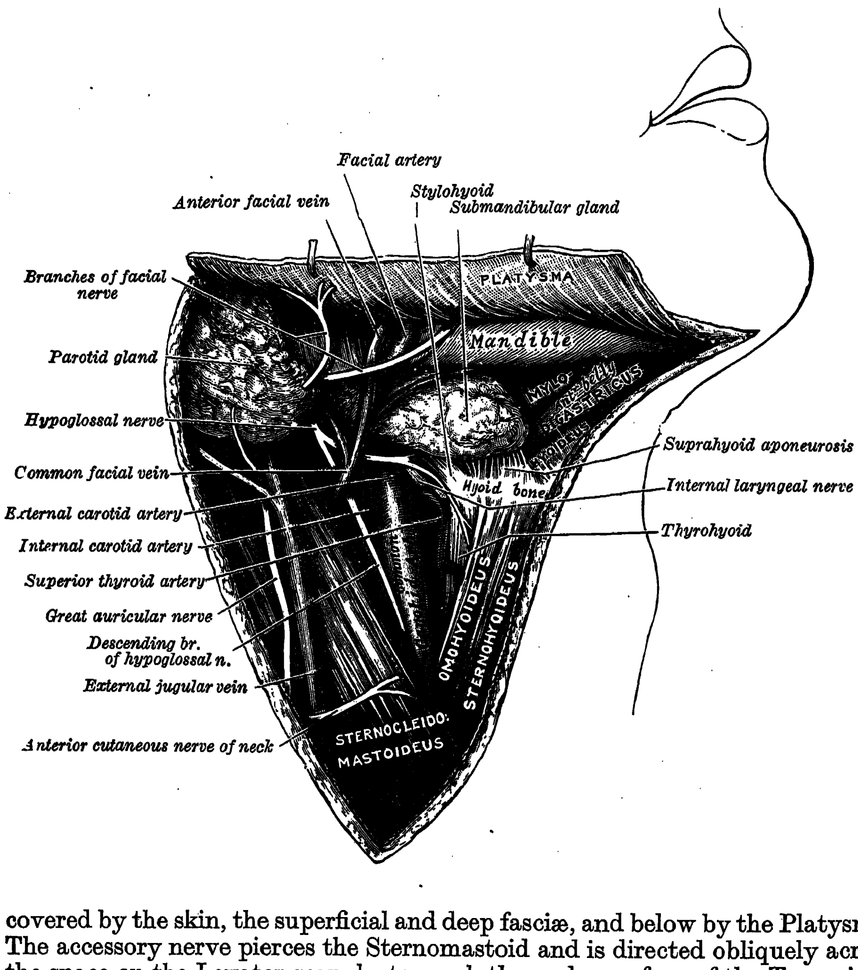
THE POSTERIOR TRIANGLE OF THE NECK (fig. 709)

The **posterior triangle** of the neck is bounded, in front, by the Sternomastoid ; behind, by the anterior margin of the Trapezius ; its base is formed by the

middle one-third of the clavicle; its apex is at the occipital bone between the attachments of the Sternomastoid and the Trapezius. The triangle is crossed, about 2·5 cm. above the clavicle, by the inferior belly of the Omohyoid, which divides the triangle into an occipital and a supraclavicular triangle.

The **occipital triangle**, the upper and larger division of the posterior triangle, is bounded in front by the Sternomastoid; behind, by the Trapezius; below, by the Omohyoid. Its floor is formed from above downwards by the Splenius capitis, Levator scapulæ, and the Scaleni medius et posterior; sometimes a small part of the Semispinalis capitis is seen at the apex of the triangle. It is

FIG. 710.—A drawing of a dissection of the carotid triangle of the neck.

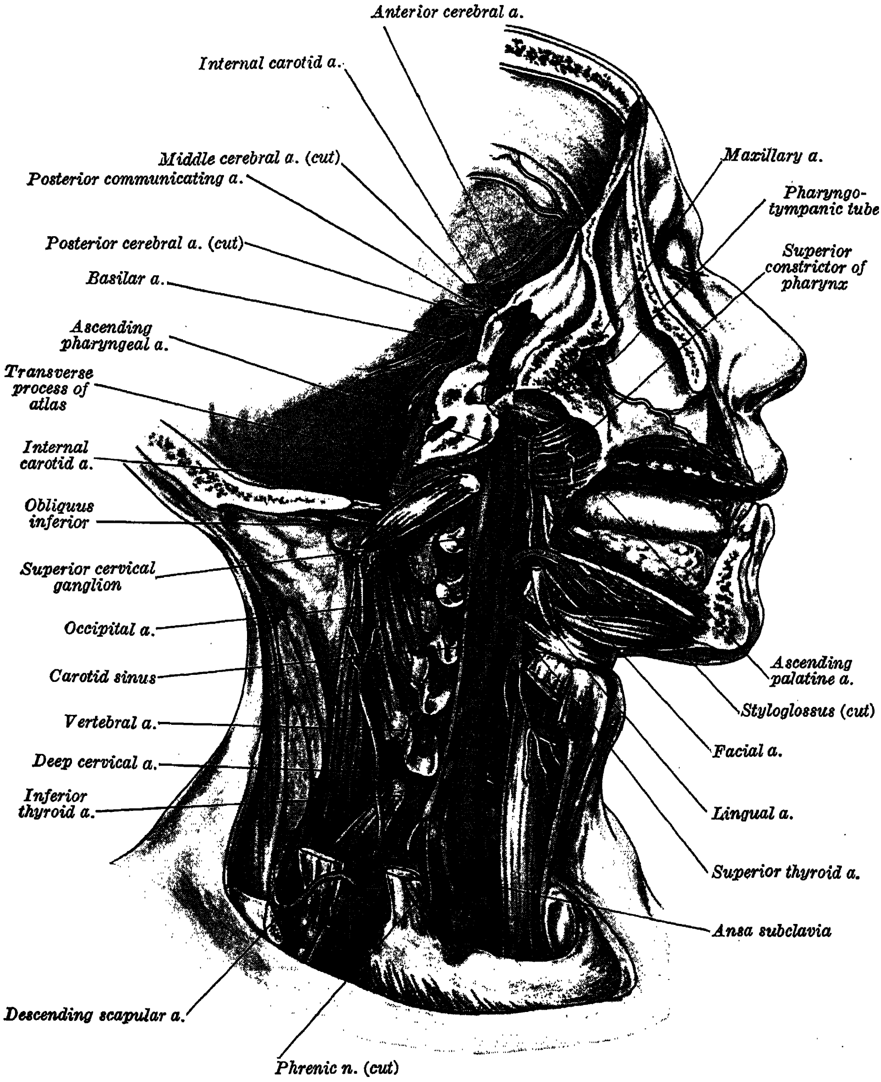


covered by the skin, the superficial and deep fasciæ, and below by the Platysma. The accessory nerve pierces the Sternomastoid and is directed obliquely across the space on the Levator scapulæ to reach the under surface of the Trapezius; the cutaneous and muscular branches of the cervical plexus appear at the posterior border of the Sternomastoid; below, the supraclavicular nerves and the transverse cervical vessels and the upper part of the brachial plexus cross the space. A chain of lymph glands is also found running along the posterior border of the Sternomastoid, from the mastoid process to the root of the neck.

The **supraclavicular triangle**, the lower and smaller division of the posterior triangle, is bounded, above, by the inferior belly of the Omohyoid; below, by the clavicle; its base is formed by the lower part of the posterior border of the Sternomastoid. Its floor consists of the first rib, the insertion of the Scalenus medius and the first digitation of the Serratus anterior. The size of this triangle varies with the extent of attachment of the clavicular portions of

the Sternomastoid and Trapezius, and also with the level at which the inferior belly of the Omohyoid crosses the neck; this level is lowered when the arm is raised, and raised when the arm is depressed. The triangle is covered by the skin, the superficial and deep fasciæ, and the Platysma, and crossed by the supraclavicular nerves. Just above the level of the clavicle, the third portion of the subclavian artery curves laterally and downwards from the lateral

FIG. 711.—A dissection to show the whole course of the right vertebral and internal carotid arteries.



margin of the Scalenus anterior, across the first rib, to the axilla. The subclavian vein lies behind the clavicle, and is not usually seen in this space; but in some cases it rises as high as the artery, and has even been seen to accompany that vessel behind the Scalenus anterior. The brachial plexus of nerves lies partly above and partly behind the artery, and in close contact with it. The suprascapular (transverse scapular) vessels pass transversely behind the clavicle; and running in the same direction, but at a slightly higher level, are the transverse cervical artery and vein. The external jugular vein descends behind the posterior border of the Sternomastoid, to terminate in the subclavian vein; it receives the transverse cervical and suprascapular veins, which form a plexus in front of the third part of the subclavian artery, and occasionally it is joined

by a small vein which crosses the clavicle from the cephalic vein. The small nerve to the Subclavius also crosses this triangle about its middle, and some lymph glands are contained within the space.

The Internal Carotid Artery

The **internal carotid artery** (fig. 711) supplies the greater part of the cerebral hemisphere, the eye and its appendages, and sends branches to the forehead and nose. It begins at the bifurcation of the common carotid artery, where it usually presents a localised dilatation, termed the carotid sinus (p. 700). It ascends to the base of the skull, and enters the cranial cavity through the carotid canal of the temporal bone. It then runs forward through the cavernous sinus, lying in the carotid groove on the side of the body of the sphenoid bone, and ends below the anterior perforated substance of the brain by dividing into the anterior and the middle cerebral arteries.

The internal carotid artery may accordingly be divided into four portions : cervical, petrous, cavernous and cerebral.

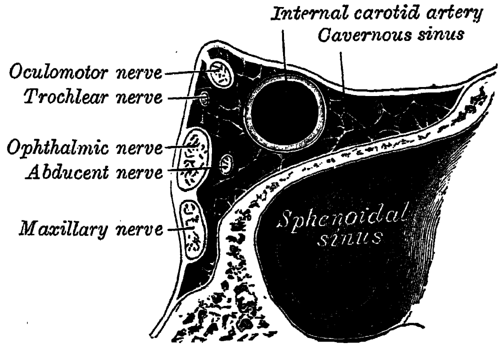
The cervical portion.—This portion of the internal carotid artery begins at the bifurcation of the common carotid artery, at the upper border of the thyroid cartilage, and ascends in front of the transverse processes of the upper three cervical vertebræ to the lower end of the carotid canal in the petrous portion of the temporal bone. It is comparatively superficial at its commencement, where it is contained in the carotid triangle, but after passing deep to the posterior belly of the Digastric muscle it lies on a much deeper plane. It presents important relations with the *internal jugular vein*, the *vagus nerve* and the *external carotid artery*. Except at the base of the skull, the internal jugular vein and the vagus nerve lie on its lateral side ; the external carotid artery is at first anterior and medial to the internal carotid but on leaving the carotid triangle it curves backwards so as to lie superficial to the vessel.

The cervical portion of the internal carotid artery has many additional relations. *Posteriorly*, it rests on the Longus capitis muscle, but the superior cervical sympathetic ganglion intervenes and the superior laryngeal nerve crosses obliquely behind the vessel. *Medially*, the artery is related to the wall of the pharynx (from which it is separated by an interval containing some fat, connective tissue and the pharyngeal veins), the ascending pharyngeal artery and the superior laryngeal nerve. *Anterolaterally*, the internal carotid artery is covered throughout by the Sternomastoid muscle. In addition, *below the Digastric*, the hypoglossal nerve and its descending branch, the lingual and common facial veins are superficial to the artery. *At the level of the Digastric* the vessel is crossed by the Stylohyoid muscle and by the occipital and posterior auricular arteries. *Above the Digastric*, it is separated from the external carotid artery by the styloid process, the Styloglossus and Stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus and the deeper part of the parotid gland. At the base of the skull the glossopharyngeal, vagus, accessory and hypoglossal nerves are between the internal carotid artery and the internal jugular vein, which here lies posterior to the artery.

The petrous portion.—When the internal carotid artery enters the carotid canal in the petrous portion of the temporal bone, it first ascends, and then curves forwards and medially. As it leaves the canal to enter the cranial cavity, it runs upwards and medially across the upper part of the foramen lacerum and above the fibrocartilage which it contains. Finally, it passes between the lingula and petrosal process of the sphenoid bone. The artery lies at first in front of the cochlea and tympanic cavity ; it is separated from the latter cavity and from the pharyngotympanic tube (auditory tube) by a thin, bony lamella, which is cribriform in the young subject, and often partly absorbed in old age. Farther forwards it is separated from the trigeminal ganglion by a thin plate of bone, which forms the floor of the trigeminal impression and the roof of the horizontal portion of the carotid canal ; frequently this bony plate is more or less deficient. The artery is surrounded by a number of small veins and by the carotid plexus of nerves, which is derived from the internal carotid branch of the superior cervical ganglion of the sympathetic trunk.

The **cavernous portion** of the internal carotid artery is situated in the cavernous sinus, but is covered by the lining endothelium of the sinus. It at first ascends towards the posterior clinoid process, then passes forwards on the side of the body of the sphenoid, and again curves upwards on the medial side of the anterior clinoid process, and perforates the dura mater forming the roof of the sinus; occasionally the anterior and middle clinoid processes form a bony ring round the artery. The cavernous portion of the artery is surrounded by a sympathetic plexus, and the oculomotor, trochlear, ophthalmic and abducent nerves (fig. 712) are on its lateral side.

Fig. 712.—An oblique section through the left cavernous sinus.



The **cerebral portion.**—After perforating the dura mater at the medial side of the anterior clinoid process, the internal carotid artery turns backwards below the optic nerves, and then passes between the optic and oculomotor nerves to the anterior perforated substance at the medial end of the lateral cerebral sulcus, where it divides into the anterior and middle cerebral arteries.

Peculiarities.—The length of the internal carotid artery varies with the length of the neck, and with the point of bifurcation of the common carotid. It arises occasionally from the arch of the aorta, and then has been found on the medial side of the external carotid, as far as the larynx, where it crossed behind the latter vessel to reach its usual position. The course of the cervical part of the artery, instead of being straight, may be very tortuous. When this occurs the vessel approaches nearer to the pharynx than usual, and may lie directly lateral to the tonsil.* A few instances are recorded in which it was absent; in one of these the common carotid artery passed up the neck, and gave off the branches normally arising from the external carotid; the cranial portion of the internal carotid artery was replaced by two branches of the maxillary artery, which entered the skull through the foramen rotundum and foramen ovale, and joined to form a single vessel.

Applied Anatomy.—Obstruction of the internal carotid by embolism or thrombosis may give rise to symptoms of cerebral anæmia and softening if the collateral circulation is ill-developed. The patient suffers from giddiness, with failure of the mental powers; and convulsions, coma, or hemiplegia on the opposite side of the body, may be observed.

Branches.—No branches arise from the cervical portion of the internal carotid artery. Those from the other portions are:

From the petrous portion	1. Caroticotympanic. 2. Pterygoid.
From the cavernous portion	3. Cavernous. 4. Hypophyseal. 5. Meningeal. 6. Ophthalmic.
From the cerebral portion	7. Anterior cerebral. 8. Middle cerebral. 9. Posterior communicating. 10. Anterior choroid.

1. The **caroticotympanic branch** is small; it enters the tympanic cavity through a foramen in the wall of the carotid canal, and anastomoses with the anterior tympanic branch of the maxillary artery, and with the stylomastoid artery.

2. A small, inconstant **pterygoid branch** passes into the pterygoid canal with the nerve of that canal, and anastomoses with a branch of the greater palatine artery.

* Consult an article by John Cairney, *Journal of Anatomy*, vol. lix. page 87.

3. The **cavernous branches** are numerous small vessels which supply the trigeminal ganglion, and the walls of the cavernous and inferior petrosal sinuses. Some of them anastomose with branches of the middle meningeal artery.

4. The **hypophyseal branches** are one or two minute vessels which supply the hypophysis cerebri.

5. The **meningeal branch** is a minute branch which passes over the lesser wing of the sphenoid to supply the dura mater of the anterior cranial fossa ; it anastomoses with the meningeal branch from the posterior ethmoidal artery.

6. The **ophthalmic artery** (fig. 713) arises from the internal carotid artery, as that vessel emerges from the cavernous sinus on the medial side of the anterior clinoid process ; it enters the orbital cavity through the optic foramen, below and lateral to the optic nerve. In the orbital cavity it runs for a short distance lateral to the optic nerve and medial to the oculomotor and abducent nerves, the ciliary ganglion and the Rectus lateralis. It next crosses obliquely above the optic nerve and below the Rectus superior to reach the medial wall of the orbit. It then runs forwards between the Obliquus superior and the Rectus medialis, and, at the medial end of the upper eyelid, divides into two branches, named *supratrochlear* (frontal) and *dorsal nasal*. As the artery crosses the optic nerve it is accompanied by the nasociliary nerve, and is separated from the frontal nerve by the Rectus superior and Levator palpebræ superioris ; the terminal part of the artery is accompanied by the infratrochlear nerve. In about 15 per cent. of subjects the ophthalmic artery crosses below the optic nerve.

The branches of the ophthalmic artery are :

Central artery of the retina.	Long posterior ciliary.	Meningeal.
Lacrimal.	Anterior ciliary.	Medial palpebral.
Muscular.	Supra-orbital.	Supratrochlear.
Short posterior ciliary.	Posterior ethmoidal.	Dorsal nasal.
	Anterior ethmoidal.	

The **central artery of the retina**, the first and one of the smallest branches of the ophthalmic artery, arises from that vessel whilst it lies below the optic nerve. It runs for a short distance within the dural sheath of the optic nerve, and about 1·25 cm. behind the eyeball it pierces the inferomedial surface of the nerve, and runs forward in the centre of the nerve to the retina. Its mode of distribution is described with the anatomy of the eye (p. 1176).

The **lacrimal artery** arises from the ophthalmic artery close to the optic foramen, and is one of its largest branches ; sometimes it is given off before the ophthalmic artery enters the orbit ; occasionally its place is taken by a branch of the middle meningeal artery (p. 713). It accompanies the lacrimal nerve along the upper border of the Rectus lateralis, and supplies the lacrimal gland. Its terminal branches, escaping from the gland, are distributed to the eyelids and conjunctiva : of those supplying the eyelids, two are of considerable size and are named the **lateral palpebral arteries** ; they run medially in the upper and lower lids respectively and anastomose with the medial palpebral arteries. The lacrimal artery gives off one or two **zygomatic branches**, one of which passes through the zygomaticotemporal foramen to the temporal fossa, and anastomoses with the deep temporal arteries ; another appears on the cheek through the zygomaticofacial foramen and anastomoses with the transverse facial artery. A **recurrent meningeal branch** passes backwards through the lateral part of the superior orbital fissure and anastomoses with a branch of the middle meningeal artery.

The **muscular branches** frequently spring from a common trunk. They consist of a superior and an inferior group, and most of them accompany the branches of the oculomotor nerve. The superior group supplies the Levator palpebræ superioris, Recti superior et lateralis, and Obliquus superior. The inferior group, more constantly present, is distributed to the Recti medialis et inferior, and the Obliquus inferior. This group gives off most of the anterior ciliary arteries. Additional muscular branches are derived from the lacrimal and supra-orbital arteries, or from the trunk of the ophthalmic artery.

The **ciliary arteries** are divisible into three groups, long and short posterior, and anterior.

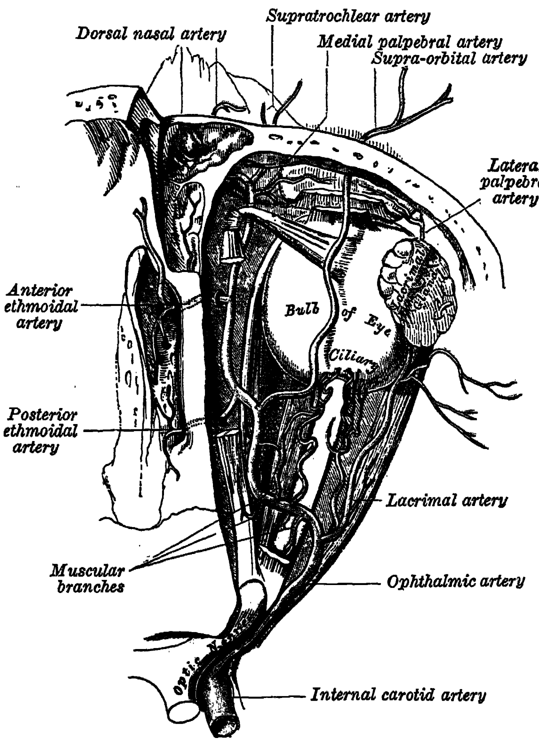
The **long posterior ciliary arteries**, two in number, pierce the posterior part of the sclera a short distance from the entrance of the optic nerve, and run forwards, one on each side of the eyeball, between the sclera and choroid, to the ciliary muscle, where each divides into a superior and an inferior branch ; these form, together with the anterior ciliary arteries,

a *greater arterial circle*, around the circumference of the iris, from which numerous converging branches run in the substance of the iris to its pupillary margin, where they form a *lesser arterial circle*.

The **short posterior ciliary arteries**, about seven in number, pass forwards around the optic nerve to the posterior part of the eyeball, and, after dividing into from fifteen to twenty branches, pierce the sclera around the entrance of the nerve, and supply the choroid coat and the ciliary processes. At the entrance of the optic nerve they anastomose with twigs of the central artery of the retina, and at the ora serrata with branches of the long posterior and anterior ciliary arteries.

The **anterior ciliary arteries** are derived from the muscular branches of the ophthalmic artery; they run to the front of the eyeball in company with the tendons of the Recti, form a vascular zone beneath the conjunctiva, and then pierce the sclera a short distance from the sclerocorneal junction and end in the greater arterial circle.

FIG. 713.—The ophthalmic artery and its branches.



The **supra-orbital artery** leaves the ophthalmic artery as that vessel crosses the optic nerve. It ascends on the medial borders of the Rectus superior and Levator palpebræ superioris, and meeting the supra-orbital nerve accompanies it between the periosteum and Levator palpebræ superioris to the supra-orbital foramen; passing through this foramen it divides into a superficial and a deep branch, which supply the skin, muscles and pericranium of the forehead, anastomosing with the supratrochlear (frontal) artery, the anterior branch of the superficial temporal artery, and the artery of the opposite side. In the orbit it supplies twigs to the Rectus superior and the Levator palpebræ, and sends a branch across the pulley of the Obliquus superior, to the parts at the medial angle of the eye. At the supra-orbital foramen it frequently sends a branch to the diploë of the frontal bone.

The **posterior ethmoidal artery** runs through the posterior ethmoidal canal, supplies the posterior ethmoidal sinuses, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches which descend into the nasal cavity through the cribriform plate of the ethmoid bone, to anastomose with branches of the sphenopalatine artery.

The **anterior ethmoidal artery** accompanies the anterior ethmoidal nerve through the anterior ethmoidal canal, supplies the anterior and middle ethmoidal and frontal sinuses, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches; the latter descend into the nasal cavity with the anterior ethmoidal nerve and, running along the groove on the inner surface of the nasal bone, supply twigs to the lateral wall and septum of the nose, and a terminal branch which appears on the dorsum of the nose between the nasal bone and the upper nasal cartilage.

The **meningeal branch** is a small branch which passes backwards through the superior orbital fissure to the middle cranial fossa, and anastomoses with the middle and accessory meningeal arteries.

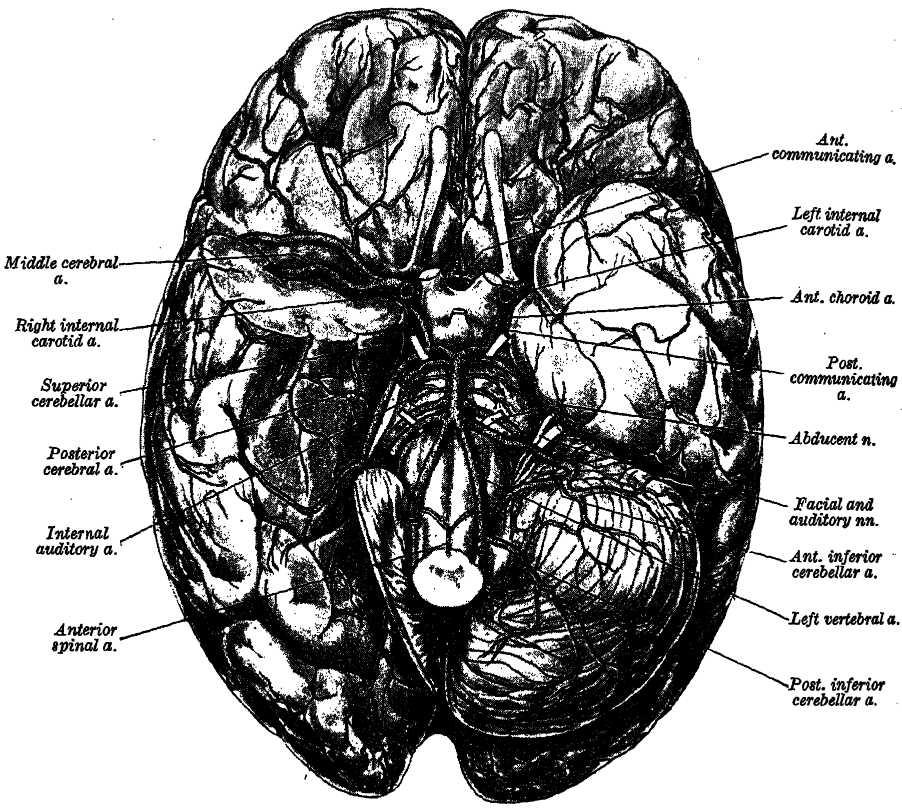
The **medial palpebral arteries**, two in number, superior and inferior, arise from the ophthalmic artery below the pulley of the Obliquus superior. They descend behind the lacrimal sac, and enter the eyelids, where each divides into two branches which course laterally along the edges of the tarsi, thus forming two arches (a superior and an inferior) in each eyelid. The superior palpebral artery anastomoses with the supra-orbital artery, and, at the lateral part of the eyelid, with the zygomatic branch of the superficial temporal artery, and with the upper of the two lateral palpebral branches of the lacrimal artery. The inferior palpebral artery anastomoses at the lateral part of the eyelid with the lower

of the two lateral palpebral branches of the lacrimal artery and with the transverse facial artery, and at the medial part of the eyelid with a twig from the facial (external maxillary) artery; from this last anastomosis a branch passes to the nasolacrimal duct, ramifying in its mucous membrane, as far as the inferior meatus of the nasal cavity.

The **supratrochlear artery** (frontal artery), one of the terminal branches of the ophthalmic artery, leaves the orbital opening at its upper medial angle, with the supratrochlear nerve, and, ascending on the forehead, supplies the skin, muscles and pericranium, anastomosing with the supraorbital artery and with the artery of the opposite side.

The **dorsal nasal artery**, the other terminal branch of the ophthalmic artery, emerges from the orbit between the trochlea of the Obliquus superior and the medial palpebral

FIG. 714.—The arteries at the base of the brain.



The right temporal pole and most of the right hemisphere of the cerebellum have been removed.

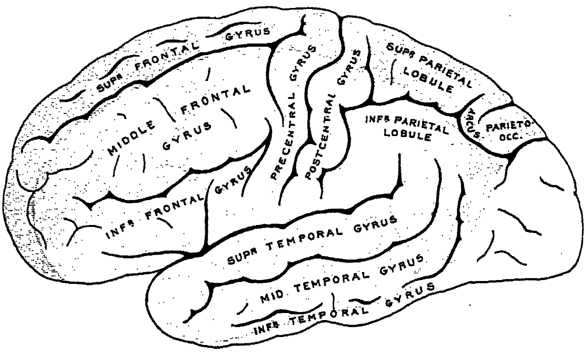
ligament, and, after giving a twig to the upper part of the lacrimal sac, divides into two branches, one of which crosses the root of the nose, and anastomoses with the terminal part of the facial artery; the other runs along the dorsum of the nose, supplies its outer surface, and anastomoses with the artery of the opposite side, and with the lateral nasal branch of the facial artery.

7. The **anterior cerebral artery** (figs. 714, 715, 716) arises from the internal carotid artery, at the medial end of the lateral cerebral sulcus. It passes forwards and medially above the optic nerve, to the commencement of the longitudinal fissure. Here it comes into close relationship with the opposite artery and is joined to it by a short transverse trunk (sometimes duplicated) named the anterior communicating artery. From this point, the two anterior cerebral arteries run side by side in the longitudinal cerebral fissure, curving round the genu of the corpus callosum, and running backwards along the upper

surface of this structure to its posterior extremity, where they end by anastomosing with the posterior cerebral arteries.

The *anterior communicating artery* has an average length of about 4 mm. and connects the two anterior cerebral arteries across the commencement of the

FIG. 715.—The lateral surface of the cerebral hemisphere, showing the areas supplied by the cerebral arteries. In this and the next figure the areas supplied by the anterior cerebral artery are coloured *blue*; those by the middle cerebral artery, *pink*; and those by the posterior cerebral artery, *yellow*.



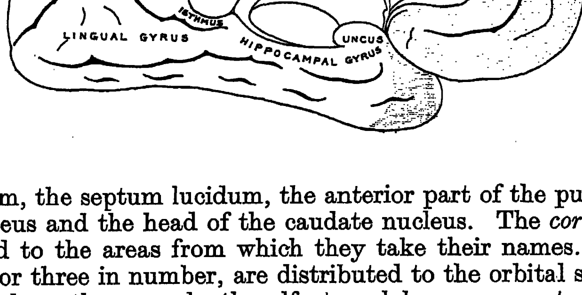
longitudinal fissure; in about 7 per cent. of subjects it is double. It gives off a few anteromedial central branches.

In its course the anterior cerebral artery gives off the following branches:

Central.	Cortical { Orbital. Frontal. Parietal.

The *central branches* are a group of small arteries which arise from the commencement of the anterior cerebral artery; they pierce the anterior perforated substance and lamina terminalis, and supply the rostrum of the

FIG. 716.—The medial surface of the cerebral hemisphere, showing the areas supplied by the cerebral arteries (see description of fig. 715).



corpus callosum, the septum lucidum, the anterior part of the putamen of the lentiform nucleus and the head of the caudate nucleus. The *cortical branches* are distributed to the areas from which they take their names. The *orbital branches*, two or three in number, are distributed to the orbital surface of the frontal lobe, where they supply the olfactory lobe, gyrus rectus and medial orbital gyrus. The *frontal branches* supply the corpus callosum, the cingulate gyrus, the medial frontal gyrus and the paracentral lobule, and send twigs over the superomedial border of the cerebral hemisphere to the superior and middle frontal gyri and the upper part of the precentral gyrus. The *parietal branches* supply the precuneus and adjacent lateral surface of the hemisphere.

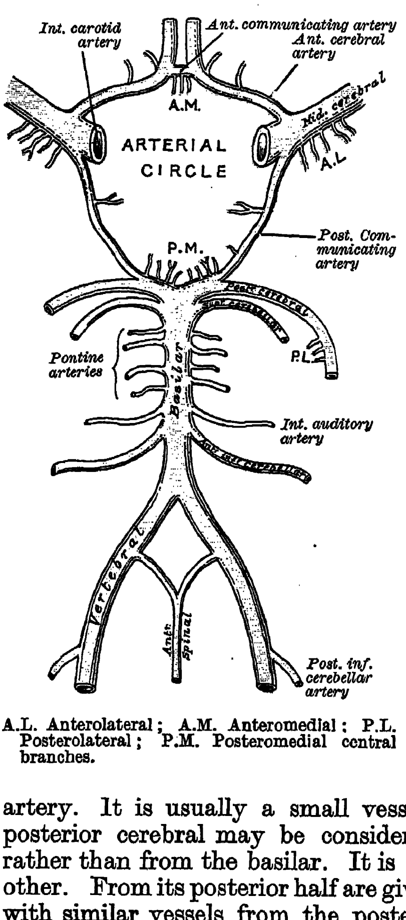
8. The **middle cerebral artery** (figs. 714, 715), the largest branch of the internal carotid artery, runs at first laterally in the lateral cerebral sulcus and then backwards and upwards on the surface of the insula, where it divides into branches which are distributed to the insula and to the lateral surface of the cerebral hemisphere.

The branches of the middle cerebral artery are the

Central.	Cortical { Orbital. Frontal. Parietal. Temporal.

The *central branches* comprise a group of small arteries which arise from the commencement of the middle cerebral artery and enter the substance of the brain through the anterior perforated substance.* They are arranged in two sets: one, termed the *medial striate*, ascends through the lentiform nucleus, and supplies it, the caudate nucleus, and the internal capsule; the other, termed the *lateral striate*, ascends over the lower part of the lateral aspect of the lentiform nucleus and then, bending medially, traverses the nucleus and the internal capsule to reach and supply the caudate nucleus. One artery of this group is larger than the rest, and of special importance as being the artery in the brain most frequently ruptured; it has been termed by Charcot the '*artery of cerebral hæmorrhage*.' Of the *cortical branches*, the *orbital branches* supply the inferior frontal gyrus and the lateral part of the orbital surface of the frontal lobe. The *frontal* supplies the precentral and the middle frontal gyrus. The *parietal branches*, two in number, are distributed to the postcentral gyrus, the lower part of the superior parietal lobule, and the whole of the inferior parietal lobule. The *temporal branches*, two or three in number, are distributed to the lateral surface of the temporal lobe.

FIG. 717.—A diagram of the arteries at the base of the brain.



A.L. Anterolateral; A.M. Anteromedial; P.L. Posterolateral; P.M. Posteromedial central branches.

9. The **posterior communicating artery** (figs. 714, 717) runs backwards from the internal carotid above the oculomotor nerve, and anastomoses with the posterior cerebral, a branch of the basilar artery. It is usually a small vessel, but is occasionally so large that the posterior cerebral may be considered as arising from the internal carotid rather than from the basilar. It is frequently larger on one side than on the other. From its posterior half are given off several small *central branches*, which, with similar vessels from the posterior cerebral artery, pierce the posterior perforated substance and supply the medial surface of the thalamus and the walls of the third ventricle.

10. The **anterior choroid artery**,† a small but constant branch, arises from the internal carotid, near the posterior communicating artery. Passing backwards above the medial part of the uncus, it crosses the optic tract and comes into

* Consult an article on "The Basal Arteries of the Forebrain," by Joseph L. Shellshear, *Journal of Anatomy*, vol. lv. 1920.

† Consult articles by A. A. Abbie on "The Blood-Supply of the Lateral Geniculate Body, with a Note on the Morphology of the Choroidal Arteries," *Journal of Anatomy*, vol. lxvii. 1933, and "The Morphology of the Forebrain Arteries," *Journal of Anatomy*, vol. lxviii. 1934.

relation with the basis pedunculi, to which it gives several minute branches. It then turns laterally, again crossing the optic tract, and comes into relation with the lateral aspect of the lateral geniculate body, to which it supplies a number of branches. Finally it enters the inferior horn of the lateral ventricle through the choroidal fissure and terminates in the choroid plexus. In addition, it supplies branches to the globus pallidus, the posterior limb of the internal capsule, the optic radiation, the optic tract, the hippocampus and the fimbria.

The circulus arteriosus.—A considerable part of the brain is supplied by the two vertebral arteries (p. 732), and a remarkable anastomosis, named the *circulus arteriosus*, exists between these vessels and the two internal carotid arteries. This circle is situated in the cisterna interpeduncularis at the base of the brain, and encloses the optic chiasma and the structures in the interpeduncular fossa (p. 971). It is formed as follows : in front, the two anterior cerebral arteries are joined to each other by the anterior communicating artery ; behind, the basilar artery (formed by the union of the vertebral arteries) divides into the two posterior cerebral arteries, each of which is joined to the internal carotid artery of the same side by the posterior communicating artery (fig. 717).

THE ARTERIES OF THE BRAIN

The mode of distribution of the vessels of the brain has an important bearing upon a considerable number of the pathological lesions which may occur in this part of the nervous system.

The arteries which supply the brain give origin to two systems of vessels. One of these is named the **central system**, and its vessels supply the thalami and corpora striata ; the other is the **cortical system**, and its vessels ramify in the pia mater and supply the cortex and subjacent brain-substance. These two systems are independent of each other and do not communicate at any point of their peripheral distribution, and there is between the parts supplied by them a borderland of diminished nutritive activity where, it is said, softening of the brain is especially liable to occur.

The central system.—All the vessels of this system are given off from the circulus arteriosus, or from the vessels close to it. They form six principal groups: (I) an **anteromedial group**, derived from the anterior cerebral and anterior communicating arteries ; (II) a **posteromedial group**, from the posterior cerebral and posterior communicating arteries ; (III and IV) right and left **anterolateral groups**, from the middle cerebral arteries ; and (V and VI) right and left **posterolateral groups**, from the posterior cerebral arteries after they have wound round the cerebral peduncles. The vessels of the central system are larger than those of the cortical system, and are known as end arteries or terminal arteries—that is to say, vessels which from their origin to their termination neither supply nor receive any anastomotic branch, so that, through any one vessel only a limited area of the thalamus or corpus striatum can be injected.

The cortical system.—The vessels of this system are the terminal branches of the anterior, middle and posterior cerebral arteries. They divide in the substance of the pia mater, give off branches which penetrate the brain-cortex prependicularly, and are divisible into two classes, long and short. The **long** or **medullary arteries** pass through the grey matter and penetrate the subjacent white matter to the depth of 3 or 4 cm., without intercommunicating, and thus constitute so many independent small systems. The **short vessels** are confined to the cortex, where they form with the long vessels a compact network in the middle zone of the grey matter, the outer and inner zones being sparingly supplied with blood. The vessels of the cortical system are not so strictly ' terminal ' as those of the central system, but they approach this type very closely, for, although neighbouring vessels anastomose with one another very freely on the surface of the brain, they become end arteries as soon as they pierce its substance.

THE ARTERIES OF THE UPPER LIMB

The artery which supplies the upper limb runs as a single trunk as far as the elbow ; but it is differently named, according to the regions it traverses. From its origin to the outer border of the first rib it is termed *subclavian* ; from the outer border of the first rib to the lower border of the tendon of the Teres major it is named *axillary* ; and from the lower border of the Teres major to a point opposite the neck of the radius it is called *brachial*.

The Subclavian Arteries

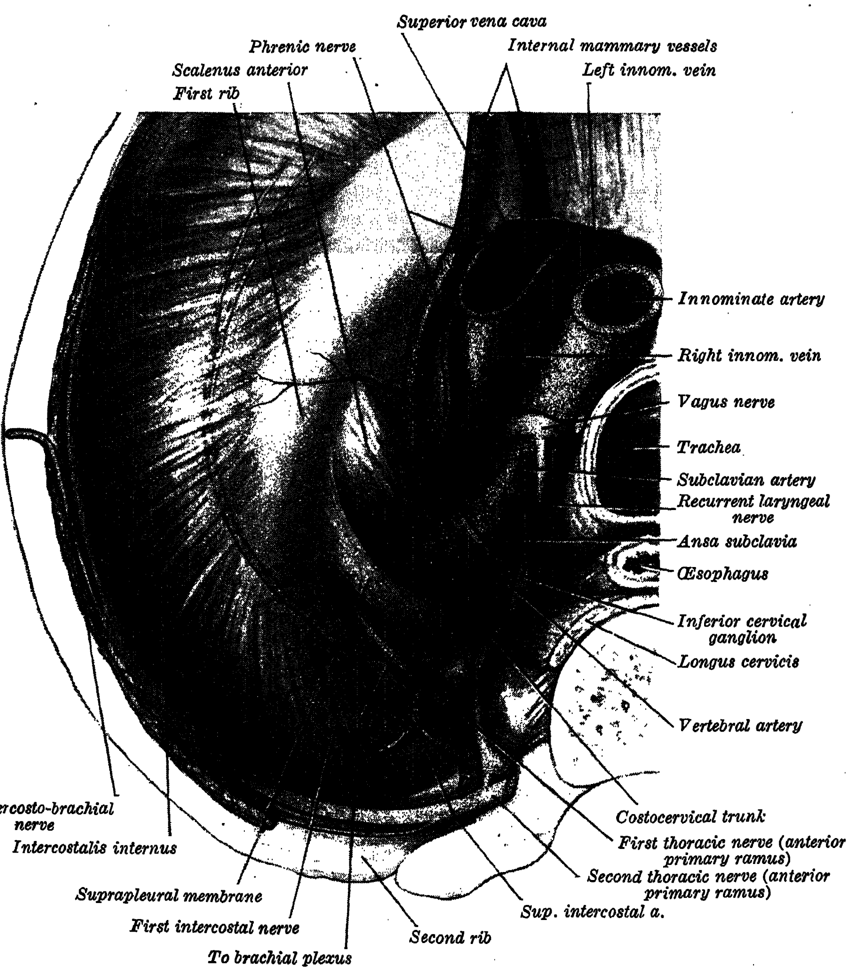
The right subclavian artery arises from the innominate artery; the left, from the arch of the aorta. The vessels, therefore, in the first parts of their courses, differ in their length, direction and relations.

To facilitate description, each subclavian artery is divided into three parts; the first extends from the origin of the vessel to the medial border of the Scalenus anterior, the second lies behind this muscle, and the third runs from the lateral margin of the muscle across the first rib to its outer border, where it becomes the axillary artery; each artery arches over the cervical portion of the pleura. The first portions of the two vessels differ from one another in their origin, course and relations, and therefore require separate descriptions. The relations of the second and third parts are almost alike on the two sides of the neck.

The First Part of the Right Subclavian Artery (figs. 718, 719)

The **first part** of the **right subclavian artery** arises from the innominate artery, behind the upper part of the right sternoclavicular joint, and passes

Fig. 718.—Structures in relation with the cervical pleura of the right side. Seen from below.



upwards and laterally to the medial margin of the Scalenus anterior. It ascends, on an average, about 2 cm. above the clavicle, but the height it reaches varies considerably in different cases.

Relations.—*In front*, the artery is covered by the skin, superficial fascia, Platysma, medial supraclavicular nerves, deep fascia, the clavicular origin of the Sternomastoid, the Sternohyoid and Sternothyroid. At its origin it is placed behind the origin of the right common carotid artery ; more laterally it is crossed by the vagus nerve and the cardiac branches of the vagus and sympathetic, by the internal jugular and vertebral veins ; the subclavian loop of the sympathetic trunk encircles the vessel. The anterior jugular vein is directed laterally in front of the artery, but is separated from it by the Sternohyoid and Sternothyroid. *Below and behind*, the artery is related to the pleura and the apex of the lung, but it is separated from them by the suprapleural membrane (p. 1247), the ansa subclavia, a small accessory vertebral vein (p. 812), and the right recurrent laryngeal nerve, which winds round the lower and posterior part of the vessel ; *behind*, the artery is related to the sympathetic trunk, the Longus cervicis (Longus colli), the right recurrent laryngeal nerve and the first thoracic vertebra.

THE FIRST PART OF THE LEFT SUBCLAVIAN ARTERY (figs. 697, 700, 703)

The **first part** of the **left subclavian artery** arises from the arch of the aorta, behind the left common carotid, usually at the level of the disc between the third and fourth thoracic vertebræ ; it ascends to the root of the neck and then arches laterally to the medial border of the Scalenus anterior.

Relations. (1) **Within the thorax.**—It is related, *in front*, to the left common carotid artery and the commencement of the left innominate vein, from which it is separated by the left vagus, cardiac and phrenic nerves. Superficial to these structures, the anterior margin of the left lung and pleura and the Sternothyroid and Sternohyoid muscles intervene between the vessel and the upper, left portion of the manubrium sterni. *Behind*, it lies, successively, on the left edge of the œsophagus, the thoracic duct and the Longus cervicis (Longus colli), and it is in contact posteriorly, on its lateral aspect, with the left lung and pleura. *Medially* it is related, successively, to the trachea, the left recurrent laryngeal nerve, the œsophagus and the thoracic duct. *Laterally* the artery grooves the mediastinal surface of the left lung and pleura, and these structures, as already indicated, tend to encroach on its anterior and posterior aspects.

(2) **Within the neck.**—Near the medial border of the Scalenus anterior the artery is crossed *anteriorly* by the left phrenic nerve and the terminal part of the thoracic duct. Otherwise the relations are the same as those previously described for the first part of the right subclavian artery. *Posteriorly* and *inferiorly*, the relations of the two vessels are identical, but the left recurrent laryngeal nerve, which was related to the left subclavian artery in the thorax, is not related to its cervical portion.

THE SECOND AND THIRD PARTS OF THE SUBCLAVIAN ARTERY (figs. 719, 720)

The **second portion** of the subclavian artery lies behind the Scalenus anterior ; it is very short, and forms the highest part of the arch described by the vessel.

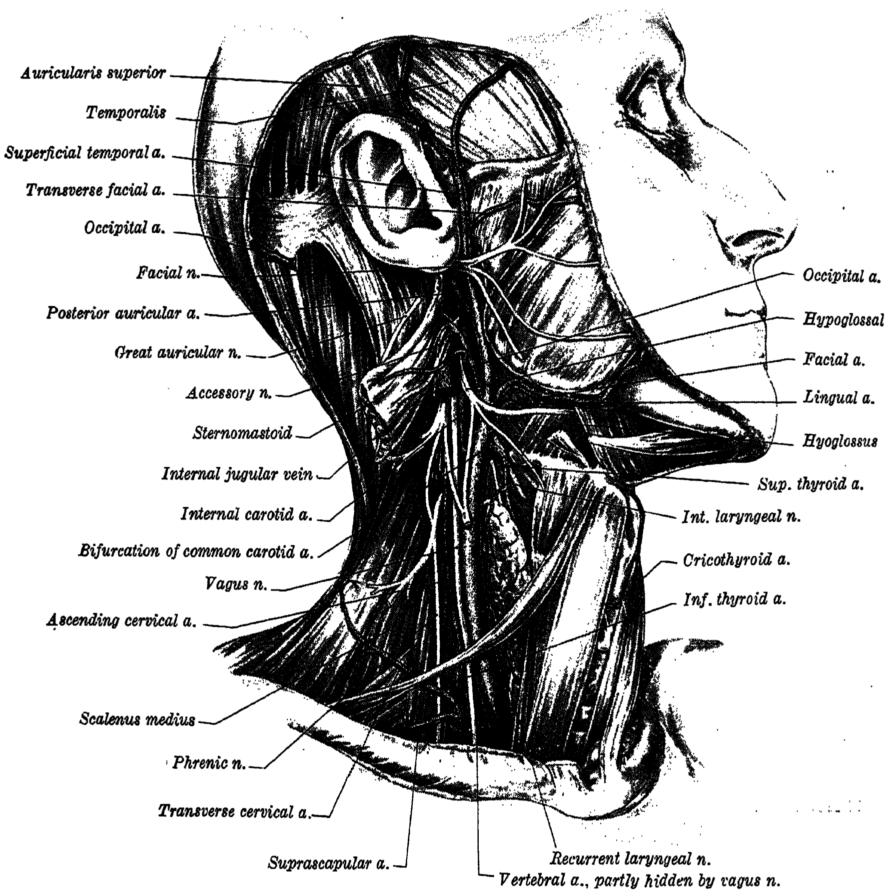
Relations.—*In front* of it are the skin, superficial fascia, Platysma, deep cervical fascia, Sternomastoid and Scalenus anterior. On the right side of the neck the phrenic nerve is separated from the second part of the artery by the Scalenus anterior, while on the left side it crosses the first part of the artery close to the medial edge of the muscle. *Behind* and *below* the vessel are the pleura and lung ; *above*, the upper and middle trunks of the brachial plexus of nerves. The subclavian vein lies below and in front of the artery, separated from it by the Scalenus anterior (fig. 720).

The **third portion** of the subclavian artery runs downwards and laterally from the lateral margin of the Scalenus anterior to the outer border of the first rib, where it becomes the axillary artery. This is the most superficial portion of the vessel, and is contained in the supraclavicular triangle (p. 718).

Relations.—*In front* of it are the skin, the superficial fascia, the Platysma, the supraclavicular nerves and the deep cervical fascia. The external jugular vein crosses its medial part and receives the suprascapular (transverse scapular), transverse cervical and anterior jugular veins, which frequently form a plexus

in front of the artery. The nerve to the Subclavius descends behind the veins and in front of the artery. The terminal part of the artery lies behind the clavicle and the Subclavius, and is crossed by the suprascapular vessels. The subclavian vein is in front of, and at a slightly lower level than, the artery. The lower trunk of the brachial plexus lies *behind* the artery and intervenes between it and the Scalenus medius. *Above*, and to its *lateral side*, are the upper and middle trunks of the brachial plexus, and the inferior belly of the Omohyoid. *Below*, it rests on the upper surface of the first rib.

FIG. 719.—A dissection of the right side of the neck showing the carotid and subclavian arteries and their branches.



The parotid and submandibular glands and the posterior belly of the digastric have been removed together with the lower part of the internal jugular vein, the upper part of the stylohyoid and the lower part of the sternomastoid muscle. The upper part of the sternomastoid muscle has been retracted to expose the structures under cover of it.

Peculiarities.—The subclavian arteries vary in their origin, their course, and the height to which they rise in the neck.

The right subclavian may arise from the innominate above or below the level of the sternoclavicular joint. It may arise as a separate trunk from the arch of the aorta, and may then be either its first or last branch. When it is the first branch, it occupies the ordinary position of the innominate artery; and when the last it arises from the left extremity of the arch, and ascends obliquely towards the right side, behind the trachea, œsophagus, and right carotid to the upper border of the first rib, whence it follows its ordinary course. In these cases, the proximal part of the artery represents a persistent part of the right dorsal aorta, and the right fourth aortic arch takes no part in its formation (p. 148). Sometimes, when it arises as the last branch of the arch of the aorta, the right subclavian artery passes between the trachea and the œsophagus.

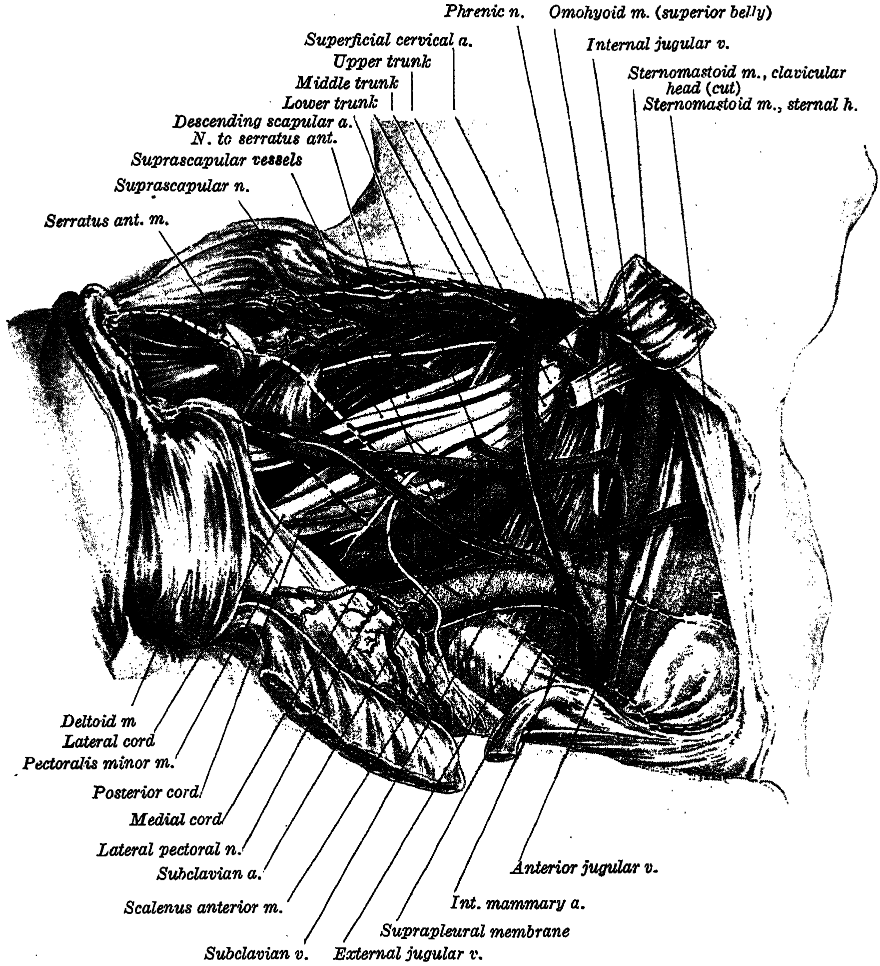
Occasionally the subclavian artery perforates the Scalenus anterior; very rarely it passes in front of that muscle. Sometimes the subclavian vein passes with the artery

behind the Scalenus anterior. The artery may ascend as high as 4 cm. above the clavicle or may only reach the level of the upper border of the bone.

The left subclavian is occasionally joined at its origin with the left carotid. It is more deeply placed than the right subclavian in the first part of its course, and, as a rule, does not reach quite as high a level in the neck.

The posterior border of the Sternomastoid corresponds closely to the lateral border of the Scalenus anterior, so that the third portion of the artery, the part most accessible for operation, lies immediately lateral to the posterior border of the Sternomastoid.

FIG. 720.—The relations of the third part of the right subclavian artery.



N.B.—The clavicle has been removed but is shown as a dotted outline.

Applied Anatomy.—An aneurysm may form on any part of the subclavian artery, except the intrathoracic portion of the left vessel, which is said never to be the seat of aneurysm. The most common site is the third portion (especially on the right side). In this situation it may cause pressure on the brachial plexus, producing pain and numbness in the arm and fingers, with loss of power or paralysis of the muscles of these parts. Œdema of the arm may result from pressure on the subclavian vein. The external jugular vein may become distended and varicose. The collateral circulation is so good that blocking of the subclavian artery by embolism or thrombosis often fails to give rise to any striking signs or symptoms, beyond occasional pains in the neck and shoulder and some degree of weakness and wasting in the muscles of the arm.

Compression of the subclavian artery may be required to control hæmorrhage, and can be applied effectually in one situation only, viz. where the artery passes across the upper surface of the first rib. In order to compress the vessel in this situation, the shoulder should be depressed and pressure exercised downwards, backwards, and medially in the angle formed by the posterior border of the Sternomastoid with the upper border of the clavicle.

Ligature of the subclavian artery may be required in cases of wounds, or of aneurysm in the axilla, or in cases of aneurysm on the cardiac side of the point of ligature.

The third part of the artery is that which is most favourable for an operation, on account of its being comparatively superficial and most remote from the origin of the large branches. In those cases where the clavicle is not displaced, this operation may be performed with comparative facility; but where the clavicle is pushed up by a large aneurysmal tumour in the axilla, the artery lies at a great depth from the surface, and this materially increases the difficulty.

The second part of the subclavian artery, the portion which rises highest in the neck, has been considered favourable for the application of the ligature when it is difficult to tie the artery in the third part of its course. There are, however, many objections to the operation in this situation. It is necessary to divide the Scalenus anterior; the phrenic nerve lies on the anterior surface of the muscle, and the internal jugular vein is situated in front of its medial edge; and a wound of either of these structures might lead to the most dangerous consequences. Again, the artery is in contact below with the pleura, which must also be avoided; and, lastly, the proximity of so many of its large branches arising medial to this point is a further objection to the operation.

In those cases of aneurysm of the axillary or subclavian artery which encroach upon the lateral portion of the Scalenus anterior to such an extent that a ligature cannot be applied in that situation, it may be deemed advisable, as a last resource, to tie the first portion of the subclavian artery. On the left side, this operation is almost impracticable; the great depth of the artery from the surface, its intimate relation with the pleura, and its close proximity to the thoracic duct and to so many important veins and nerves, present a series of difficulties which it is next to impossible to overcome. On the right side, the operation is practicable, the main difficulty being the smallness of the interval which usually exists between the commencement of the vessel and the origin of the nearest branch. The exact position of the vagus, recurrent laryngeal and phrenic nerves and the sympathetic trunk should be borne in mind, and the ligature should be applied near the origin of the vertebral, in order to afford as much room as possible for the formation of a coagulum between the ligature and the origin of the vessel.

Collateral Circulation.—After ligature of the third part of the subclavian artery, the collateral circulation is established mainly by three sets of vessels: *

1. A posterior set, consisting of the suprascapular (transverse scapular) artery and the deep branch of the transverse cervical artery, both derived from the subclavian, anastomosing with the subscapular from the axillary.
2. A medial set, produced by the connexion of the internal mammary on the one hand, with the superior intercostal, the lateral thoracic and subscapular arteries on the other.
3. A middle or axillary set, consisting of a number of small vessels derived from branches of the subclavian and, passing through the axilla, terminating either in the axillary artery, or some of its branches. In the case quoted, this last set presented most conspicuously the peculiar character of newly formed or, rather, dilated arteries, being excessively tortuous, and forming a complete plexus.

The chief agent in the restoration of the axillary artery below the aneurysm was the subscapular artery, which communicated freely with the internal mammary, suprascapular, and deep branch of the transverse cervical arteries of the subclavian, from all of which it received so great an influx of blood as to dilate it to three times its natural size.

When a ligature is applied to the first part of the subclavian artery, the collateral circulation is carried on by the following anastomoses: 1, between the superior and inferior thyroids; 2, the two vertebrals; 3, the internal mammary with the inferior epigastric and the posterior (aortic) intercostals; 4, the costocervical with the posterior intercostals; 5, the deep cervical with the descending branch of the occipital; 6, the scapular branches of the thyrocervical trunk with the branches of the axillary; and 7, the thoracic branches of the axillary with the posterior intercostals.

Branches.—The branches of the subclavian artery are:

Vertebral.	Thyrocervical trunk.
Internal mammary.	Costocervical trunk.

On the left side of the neck all four branches generally rise from the first portion of the artery; on the right side the costocervical trunk usually springs from the second portion. On both sides, the first three branches originate close together at the medial border of the Scalenus anterior.

1. The **vertebral artery** (figs. 703, 711) arises from the upper and posterior part of the first portion of the subclavian artery. It ascends through the fora-

* *Guy's Hospital Reports*, vol. i. 1836. Case of axillary aneurysm, in which Aston Key had tied the subclavian artery at the lateral edge of the Scalenus anterior, twelve years previously.

mina in the transverse processes of the upper six cervical vertebræ,* winds behind the lateral mass of the atlas, enters the skull through the foramen magnum, and, at the lower border of the pons, unites with the vessel of the opposite side to form the basilar artery.

Relations.—The vertebral artery may be divided into four parts. The *first part* runs upwards and backwards between the Longus cervicis (Longus colli) and the Scalenus anterior and behind the common carotid artery. In front it is related to the common carotid artery and the vertebral vein, and is crossed by the inferior thyroid artery; on the left side it is crossed also by the thoracic duct. Behind, it is related to the transverse process of the seventh cervical vertebra, the inferior cervical ganglion (fig. 997) and the anterior primary rami of the seventh and eighth cervical nerves. The *second part* ascends through the foramina transversaria of the upper six cervical vertebræ, and is accompanied by a large branch derived from the inferior cervical sympathetic ganglion, and by a plexus of veins which unite to form the vertebral vein at the lower part of the neck. It lies in front of the anterior primary rami of the cervical nerves (C. 2-C. 6) (fig. 703), and pursues an almost vertical course as far as the transverse process of the axis, through which it runs upwards and laterally to the foramen transversarium of the atlas. The *third part* issues from the latter foramen on the medial side of the Rectus capitis lateralis, and curves backwards behind the lateral mass of the atlas, the anterior primary ramus of the first cervical nerve being on its medial side; it then lies in the groove on the upper surface of the posterior arch of the atlas, and enters the vertebral canal by passing below the lower, arched border of the posterior atlanto-occipital membrane. This part of the artery is covered by the Semispinalis capitis and is contained in the *suboccipital triangle*, which is bounded by the Rectus capitis posterior major, the Obliquus superior and the Obliquus inferior. The posterior primary ramus of the first cervical nerve lies between the artery and the posterior arch of the atlas (fig. 591). The *fourth part* pierces the dura and the arachnoid mater, ascends in front of the roots of the hypoglossal nerve (fig. 839), and inclines medially to the front of the medulla oblongata, where, at the lower border of the pons, it unites with the vessel of the opposite side to form the basilar artery (fig. 714).

The branches of the vertebral artery may be divided into two sets—those given off in the neck, and those within the cranium.

Cervical branches.	*Cranial branches.*
Spinal.	Meningeal.
Muscular.	Posterior spinal.
	Anterior spinal.
	Posterior inferior cerebellar.
	Medullary.

Spinal branches enter the vertebral canal through the intervertebral foramina, and each divides into two branches. Of these, one passes along the roots of the nerves to supply the spinal cord and its membranes, anastomosing with the other arteries of the spinal cord; the other divides into an ascending and a descending branch, which unite with similar branches from the arteries above and below, so that two lateral anastomotic chains are formed on the posterior surfaces of the bodies of the vertebræ, near the attachment of the pedicles. From these anastomotic chains branches are supplied to the periosteum and the bodies of the vertebræ, and others communicate with similar branches from the opposite side; from these communications small twigs arise which join similar branches above and below, to form a central anastomotic chain on the posterior surfaces of the bodies of the vertebræ.

Muscular branches arise from the vertebral artery as it curves round the lateral mass of the atlas. They supply the deep muscles of this region and anastomose with the occipital artery, and with the ascending and deep cervical arteries.

One or two **meningeal branches** spring from the vertebral artery opposite the foramen magnum; they ramify between the bone and dura mater in the cerebellar fossa, and supply the falx cerebelli.

The **posterior spinal artery** may arise from the vertebral artery at the side of the medulla oblongata, but is most frequently derived from the posterior inferior cerebellar artery. It

* The vertebral artery sometimes enters the foramen in the transverse process of the fifth vertebra.

passes backwards, and then descends as two branches, one in front of and the other behind the posterior roots of the spinal nerves; these are reinforced by a succession of spinal twigs which arise from the vertebral, ascending cervical, posterior intercostal and lumbar arteries, and enter the vertebral canal through the intervertebral foramina; by means of these branches the posterior spinal arteries are continued to the lower part of the spinal cord, and to the cauda equina. Branches from the posterior spinal arteries form a free anastomosis with those of the opposite side. Near its origin each posterior spinal artery gives off an ascending branch, which ends at the side of the fourth ventricle.

The **anterior spinal artery** is a small branch, which arises near the termination of the vertebral artery; it descends in front of the medulla oblongata and unites with its fellow of the opposite side near the level of the lower end of the olive of the medulla oblongata. The single trunk, thus formed, descends on the front of the spinal cord, and is reinforced by a succession of small spinal branches which enter the vertebral canal through the intervertebral foramina; these branches are derived from the vertebral, the ascending cervical, posterior intercostal, and lumbar arteries. They unite, by means of ascending and descending branches, to form a single anterior median artery, which extends as far as the lower part of the spinal cord, and is continued as a slender twig on the filum terminale. This vessel is placed in the pia mater along the anterior median fissure; it supplies that membrane, and the substance of the spinal cord, and sends off branches at its lower part to be distributed to the cauda equina. Branches pass from the anterior spinal arteries, and from the beginning of the trunk formed by their union, to the medulla oblongata, where they are distributed to its central portion, being sharply limited dorsally to the region of the trigonum hypoglossi.*

The **posterior inferior cerebellar artery** (fig. 714) is the largest branch of the vertebral artery, but is not infrequently absent. It arises near, and winds backwards round, the lower end of the olive of the medulla oblongata; it then ascends behind the roots of the glossopharyngeal and vagus nerves to the lower border of the pons, where it turns downwards along the inferolateral border of the fourth ventricle. Finally, it runs laterally into the vallecula of the cerebellum, where it divides into a medial and a lateral branch. The medial branch runs backwards between the cerebellar hemisphere and the inferior vermis, supplying branches to both; the lateral branch supplies the under surface of the hemisphere, as far as its lateral border, and anastomoses with the anterior inferior cerebellar and superior cerebellar branches of the basilar artery. The trunk of the artery supplies branches to the medulla oblongata and to the choroid plexus of the fourth ventricle, and sends a branch upwards lateral to the tonsil of the cerebellum to supply the dentate nucleus of the cerebellum (Shellshear †). The area supplied in the medulla oblongata lies dorsal to the olivary nucleus (inferior olivary nucleus) and lateral to the hypoglossal nucleus and its emerging fila, and usually includes the nucleus of the spinal tract of the trigeminal nerve and the spino-thalamic tracts.

The **medullary arteries** are several minute vessels which spring from the vertebral and its branches, and are distributed to the medulla oblongata.

The **basilar artery** (figs. 714, 717), so named from its position at the base of the skull, is formed by the junction of the two vertebral arteries; it extends from the lower to the upper border of the pons, and is contained within the cisterna pontis. It lies in a shallow, median groove on the ventral surface of the pons. It is placed between the two abducent nerves at the lower border, and between the two oculomotor nerves at the upper border, of the pons, where it divides into the two posterior cerebral arteries.

Its branches, on each side, are the following:

Pontine.	Anterior inferior cerebellar.
Internal auditory.	Superior cerebellar.
Posterior cerebral.	

The **pontine branches** are a number of small vessels which come off from the front and sides of the basilar artery, and supply the pons and adjacent parts of the brain.‡

* J. L. Shellshear, *Journal of Anatomy*, vol. lxi. April, 1927.

† J. L. Shellshear, *Lancet*, May 27th, 1922.

‡ Consult an article on "The Arteries of the Pons and Medulla Oblongata," by J. S. B. Stopford, *Journal of Anatomy*, vols. l., li.

The **internal auditory artery**, a long slender branch, may arise from the lower part of the basilar artery but is more often derived from the anterior inferior cerebellar artery ; it accompanies the facial and auditory nerves into the internal auditory meatus, and is distributed to the internal ear.

The **anterior inferior cerebellar artery** (fig. 714) arises from the lower part of the basilar artery. It runs backwards and laterally, usually ventral to the abducent nerve, the facial and auditory nerves, and curves round the margin of the flocculus to be distributed to the anterior and lateral parts of the under surface of the cerebellum, where it anastomoses with the posterior inferior cerebellar branch of the vertebral artery. A few branches are supplied by the anterior inferior cerebellar artery to the lower and lateral parts of the pons, and sometimes to the upper part of the medulla oblongata.

The **superior cerebellar artery** (fig. 714) arises near the termination of the basilar. It passes laterally immediately below the oculomotor nerve, which separates it from the posterior cerebral artery, winds round the cerebral peduncle close to and below the trochlear nerve, and, arriving at the superior surface of the cerebellum, divides into branches which ramify in the pia mater, supplying this aspect of the cerebellum and anastomosing with branches of the inferior cerebellar arteries. In addition, branches are given to the pons, the pineal body, the superior medullary velum and the tela chorioidea of the third ventricle.

The **posterior cerebral artery** (figs. 714, 715, 716), frequently double, is larger than the superior cerebellar artery, from which it is separated near its origin by the oculomotor nerve, and on the side of the mesencephalon by the trochlear nerve. Passing laterally, parallel with the superior cerebellar artery, and receiving the posterior communicating branch from the internal carotid artery, it winds round the cerebral peduncle, and reaches the tentorial surface of the cerebrum, where it breaks up into branches for the supply of the temporal and occipital lobes.

The branches of the posterior cerebral artery are divided into two sets, central and cortical :

Central	Posteromedial. Posterior choroid. Posterolateral.	*Cortical*	Temporal. Occipital. Parieto-occipital.

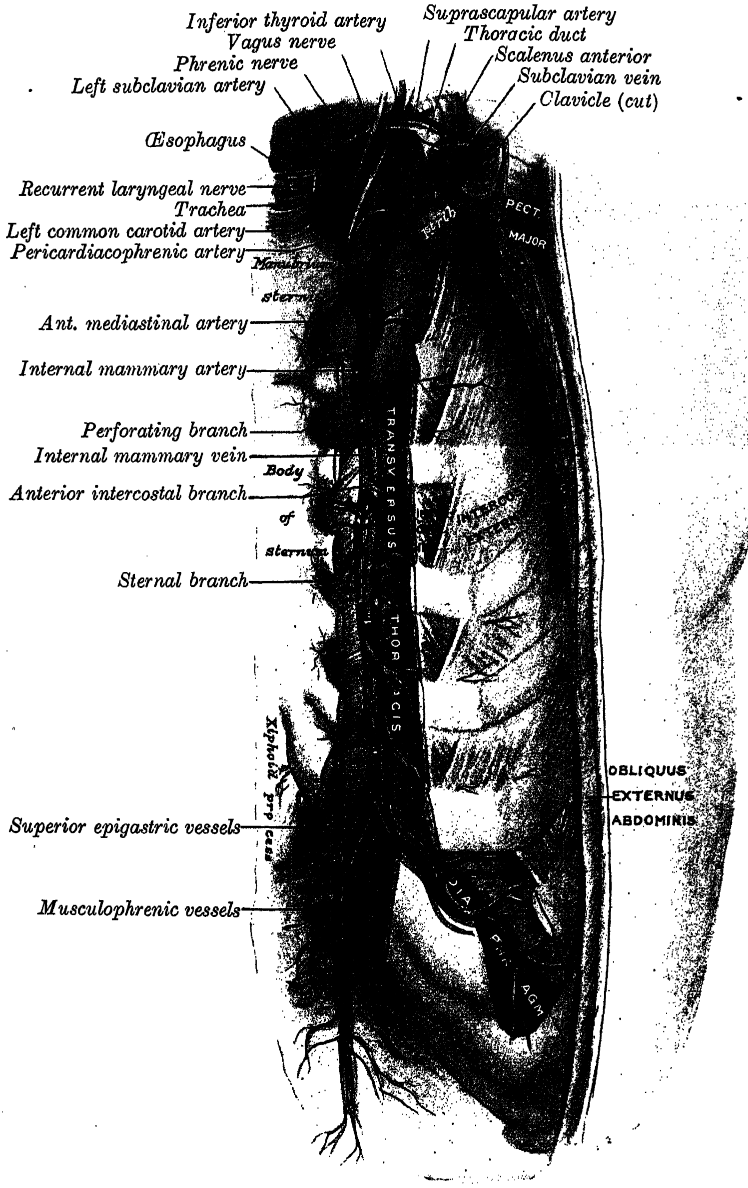
Central branches.—The *posteromedial central branches* (fig. 717) are several small arteries which arise at the commencement of the posterior cerebral artery ; these, with similar branches from the posterior communicating, pierce the posterior perforated substance, and supply the anterior part of the thalamus, the lateral wall of the third ventricle and the globus pallidus of the lentiform nucleus. The *posterior choroid branches* are usually three or four in number. One, or more, courses over the lateral geniculate body and helps to supply it, before entering the posterior part of the inferior horn through the lower part of the choroidal fissure. The others curl round the posterior end of the thalamus and pass through the transverse fissure, to enter the tela chorioidea of the third ventricle, and through the upper part of the choroidal fissure ; they supply the choroid plexuses of the third and lateral ventricles, and give some twigs to the fornix. The *posterolateral central branches* are small arteries which arise from the posterior cerebral artery after it has turned round the cerebral peduncle ; they supply the cerebral peduncle, the posterior part of the thalamus, and the pineal, quadrigeminal and medial geniculate bodies.

Cortical branches.—The *temporal branches*, usually two in number, are distributed to the uncus, the hippocampal, the medial and lateral occipito-temporal gyri ; the *occipital branches* supply the cuneus, gyrus lingualis and the posterior part of the lateral surface of the occipital lobe ; and the *parieto-occipital* supply the cuneus and the precuneus.

2. The **internal mammary artery** (fig. 721) arises from the under surface of the first portion of the subclavian artery, opposite the thyrocervical trunk. It descends behind the cartilages of the upper six ribs at a distance of 1·25 cm. from the lateral border of the sternum, and at the level of the sixth intercostal space divides into the *musculophrenic* and *superior epigastric* arteries.

Relations.—It runs at first downwards, forwards, and medially behind the sternal end of the clavicle, the internal jugular and innominate veins, and the first costal cartilage. As the artery enters the thorax, the phrenic nerve crosses it obliquely from the lateral to the medial side, the nerve usually passing in front of the artery. Below the first costal cartilage it descends almost vertically

Fig. 721.—The left internal mammary artery.



to its point of bifurcation. It is covered in front by the Pectoralis major, the cartilages of the upper six ribs and the intervening anterior intercostal membranes and Internal intercostals, and is crossed by the terminal portions of the upper six intercostal nerves. It is separated from the pleura, as far as the second or third costal cartilage, by a strong layer of fascia ; below this level, by the Sternocostalis (Transversus thoracis). It is accompanied by a chain of lymph glands and a pair of veins : about the level of the third costal cartilage

the veins unite to form a single vessel, which runs medial to the artery and ends in the innominate vein.

The branches of the internal mammary artery are:

Pericardiacophrenic.	Sternal.	Musculophrenic.
Mediastinal.	Anterior intercostal.	Superior epigastric.
Pericardial.	Perforating.	

The **pericardiacophrenic artery** is a long, slender branch which accompanies the phrenic nerve, between the pleura and pericardium, to the Diaphragm; it gives branches to the pleura, pericardium, and Diaphragm, and anastomoses with the musculophrenic and phrenic (inferior phrenic) arteries.

The **mediastinal arteries** are small vessels, distributed to the areolar tissue and lymph glands in the anterior mediastinum, and to the remains of the thymus.

The **pericardial branches** supply the upper part of the anterior surface of the pericardium.

The **sternal branches** are distributed to the Sternocostalis (Transversus thoracis) and to the posterior surface of the sternum.

The anterior mediastinal, pericardial and sternal branches, together with some twigs from the pericardiacophrenic, anastomose with branches from the posterior intercostal and bronchial arteries, and form a **subpleural mediastinal plexus.**

The **anterior intercostal branches** are distributed to the upper six intercostal spaces. Two in each space, they pass laterally, one lying near the lower margin of the upper rib, and the other near the upper margin of the lower rib, and anastomose with the posterior intercostal arteries. They are at first situated between the pleura and the Internal intercostal muscles, and then between the Intercostales intimi and the Internal intercostals. They supply the Intercostal muscles and send branches through them to the Pectoral muscles and the mamma.

The **perforating branches** emerge through the upper five or six intercostal spaces, with the anterior cutaneous branches of the corresponding intercostal nerves. They pierce the Pectoralis major, and curving laterally, supply that muscle and the skin. Those of the second, third and fourth spaces give branches to the mamma, and during lactation are of large size.

The **musculophrenic artery** is directed obliquely downwards and laterally, behind the cartilages of the seventh, eighth and ninth ribs; it perforates the Diaphragm near the ninth costal cartilage, and ends opposite the last intercostal space. It anastomoses with the phrenic artery, the lower two posterior intercostal arteries and the ascending branch of the deep circumflex iliac artery. It gives off two anterior intercostal branches to each of the seventh, eighth and ninth intercostal spaces; these are distributed in a manner similar to the anterior intercostals from the internal mammary. The musculophrenic also gives branches to the lower part of the pericardium and to the abdominal muscles.

The **superior epigastric artery** descends through the interval between the costal and xiphoid origins of the Diaphragm, lying on the lower fibres of the Sternocostalis (Transversus thoracis) and the upper fibres of the Transversus abdominis. It enters the sheath of the Rectus abdominis, at first lying behind the muscle, and then perforating and supplying it, and anastomosing with the inferior epigastric artery from the external iliac. Branches perforate the sheath of the Rectus, and supply the skin of the abdomen, and a small branch passes in front of the xiphoid process and anastomoses with the artery of the opposite side. The superior epigastric artery also gives some twigs to the Diaphragm, while from the artery of the right side small branches extend into the falciform ligament of the liver and anastomose with the hepatic artery.

3. The **thyrocervical trunk** (figs. 703, 719), a short, wide trunk, arises from the front of the first portion of the subclavian artery, close to the medial border of the Scalenus anterior, and divides almost immediately into three branches, the *inferior thyroid, suprascapular* and *transverse cervical.*

The **inferior thyroid artery** runs upwards in front of the medial border of the Scalenus anterior; it then turns medially in front of the vertebral vessels and behind the carotid sheath and its contents, and usually behind the sympathetic trunk, the middle cervical ganglion of which rests upon the vessel; it finally descends on the Longus cervicis (Longus colli) to the lower border of the lobe of the thyroid gland. At a little distance from the gland the inferior thyroid artery usually passes behind the recurrent laryngeal nerve, but when

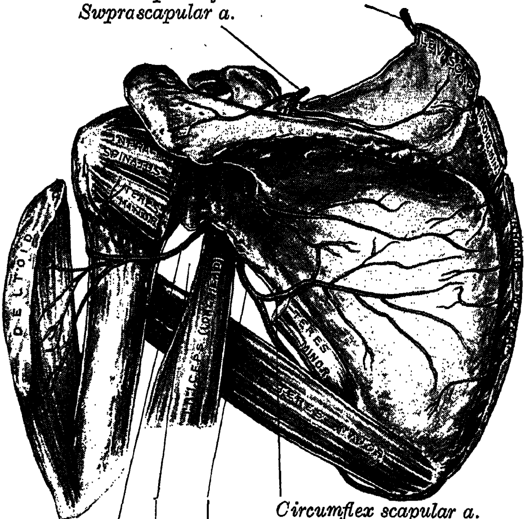
the gland is reached the nerve is often behind the branches of the artery or it may pass between them.*

The branches of the inferior thyroid are :

Muscular.	Inferior laryngeal.	Œsophageal.
Ascending cervical.	Tracheal.	Glandular.

The **muscular branches** supply the depressor muscles of the hyoid bone, the Longus cervicis, Scalenus anterior and Inferior constrictor of the pharynx.

FIG. 722.—The scapular anastomosis of the left side; dorsal aspect.



The **ascending cervical artery** is a small branch which arises from the inferior thyroid artery as that vessel turns medially behind the carotid sheath; it ascends on the anterior tubercles of the transverse processes of the cervical vertebræ in the interval between the Scalenus anterior and Longus capitis and medial to the phrenic nerve. It gives twigs to the muscles of the neck, and sends one or two spinal branches into the vertebral canal through the intervertebral foramina to be distributed to the spinal cord and its membranes, and to the bodies of the vertebræ, in the same manner as the spinal branches of the vertebral artery. It anastomoses with branches of the vertebral, ascending pharyngeal, occipital and deep cervical arteries.

The **inferior laryngeal artery** ascends upon the trachea in company with the recurrent laryngeal nerve; it enters the larynx deep to the lower border of the Inferior constrictor muscle, and supplies its muscles and mucous membrane, anastomosing with the artery from the opposite side, and with the superior laryngeal branch of the superior thyroid artery.

The **tracheal branches** are distributed to the trachea and anastomose below with the bronchial arteries.

The **œsophageal branches** supply the œsophagus and anastomose with the œsophageal branches of the descending thoracic aorta.

The **glandular branches** comprise an inferior and an ascending branch; they are distributed to the posterior and inferior parts of the thyroid gland, and anastomose with the superior thyroid artery and with the opposite inferior thyroid artery; the ascending branch supplies the superior parathyroid gland.

The **suprascapular artery** (transverse scapular artery) (fig. 720) passes at first downwards and laterally across the Scalenus anterior and the phrenic nerve, under cover of the internal jugular vein and the Sternomastoid; it then crosses the subclavian artery and the brachial plexus, and runs behind and parallel with the clavicle and Subclavius, and deep to the inferior belly of the Omohyoid, to the superior border of the scapula; here it passes above (occasionally below) the suprascapular ligament, which separates it from the suprascapular nerve, and enters the supraspinous fossa (fig. 722). In this situation it lies on the bone, and supplies branches to the Supraspinatus. It then descends behind the neck of the scapula, through the great scapular notch and deep to the spinoglenoid ligament, to reach the deep surface of the Infraspinatus, where it anastomoses with the circumflex scapular artery, and the deep branch of the transverse cervical artery. Besides distributing branches to the Sternomastoid, Subclavius, and neighbouring muscles, it gives off a *suprasternal branch*, which crosses over the sternal end of the clavicle

* F. G. Parsons, *Journal of Anatomy*, vol. liv. p. 172.

to the skin of the upper part of the chest; and an *acromial branch*, which pierces the Trapezius and supplies the skin over the acromion, anastomosing with the acromiothoracic artery. As the suprascapular artery passes above the suprascapular ligament, it sends a branch into the subscapular fossa, where it ramifies beneath the Subscapularis, and anastomoses with the subscapular artery and with the deep branch of the transverse cervical artery.. The suprascapular artery also sends articular branches to the acromioclavicular and shoulder-joints, and nutrient arteries to the clavicle and scapula. Not infrequently the suprascapular artery arises from the third part of the subclavian artery.

The **transverse cervical artery** (fig. 720) lies at a higher level than the suprascapular artery; it crosses in front of the phrenic nerve and the Scalenus anterior, and in front of the brachial plexus, and is covered by the internal jugular vein, Sternomastoid and Platysma. It crosses the floor of the posterior triangle of the neck, to reach the anterior margin of the Levator scapulæ, where it divides into a superficial and a deep branch.

The *superficial branch* ascends deep to the anterior part of the Trapezius, distributing branches to it and the neighbouring muscles, and to the lymph glands in the neck; it anastomoses with the superficial branch of the ramus descendens of the occipital artery.

The *deep branch* (fig. 722) passes under cover of the Levator scapulæ to the superior angle of the scapula, and then descends under cover of the Rhomboids along the medial border of the scapula as far as the inferior angle of the bone. It supplies branches to the Rhomboids, Latissimus dorsi and Trapezius, and anastomoses with the suprascapular and subscapular arteries, and with the posterior branches of some of the posterior intercostal arteries.

Peculiarities.—Frequently the superficial branch [superficial cervical artery] arises directly from the thyrocervical trunk, and the deep branch [descending scapular artery] from the third, more rarely from the second, part of the subclavian (fig. 726). When the deep branch arises in this way it usually passes between the upper and middle trunks of the brachial plexus.

4. The **costocervical trunk** (figs. 711, 718) arises from the back of the second part of the subclavian artery on the right side, but from the first part of the artery on the left side. It arches backwards above the cervical pleura to the neck of the first rib, and divides into the superior intercostal and deep cervical arteries.

The **superior intercostal artery** descends behind the pleura in front of the necks of the first and second ribs, and anastomoses with the third posterior (first aortic) intercostal artery. As it crosses the neck of the first rib it is medial to the anterior primary ramus of the first thoracic nerve, which it crosses at a lower level (fig. 718), and lateral to the first thoracic ganglion of the sympathetic trunk. In the first intercostal space, it gives off the first posterior intercostal artery, which is distributed in a manner similar to the distribution of the lower posterior intercostals. The second posterior intercostal artery usually joins with a branch from the third posterior (first aortic) intercostal artery; the second posterior intercostal artery is not constant, but is more commonly found on the right side; when absent, its place is supplied by a branch from the aorta.

The **deep cervical artery** (fig. 711) arises, in most cases, from the costocervical trunk, and is analogous to the posterior branch of a posterior intercostal artery: occasionally it is a separate branch from the subclavian artery. Passing backwards above the eighth cervical nerve and between the transverse process of the seventh cervical vertebra and the neck of the first rib (sometimes between the transverse processes of the sixth and seventh cervical vertebræ, it ascends on the back of the neck, between the Semispinales capitis et cervicis, as high as the second cervical vertebra, supplying the adjacent muscles, and anastomosing with the deep division of the descending branch of the occipital artery (p. 709) and with branches of the vertebral artery. It gives off a spinal twig which enters the vertebral canal through the foramen between the seventh cervical and first thoracic vertebræ.

The Axilla

The axilla is a pyramidal space, situated between the upper part of the chest wall and the upper part of the medial side of the upper arm.

The *apex* of the axilla is directed upwards towards the root of the neck, and corresponds to the interval between the outer border of the first rib, the superior border of the scapula and the posterior surface of the clavicle; through it the axillary vessels and nerves enter the space from the neck. The *base*, directed downwards, is broad at the chest but narrow and pointed at the arm; it is formed by the skin and a thick layer of fascia, termed the *axillary fascia*, extending between the lower border of the Pectoralis major in front, and the lower border of the Latissimus dorsi behind. The *anterior wall* is formed by the Pectorales major et minor, the former covering the whole of this wall, the latter only its central part. The space between the upper border of the Pectoralis minor and the clavicle is occupied by the clavipectoral fascia (costo-coracoid membrane). The *posterior wall* is formed by the Subscapularis above, the Teres major and Latissimus dorsi below. On the *medial side* are the first four ribs with their corresponding Intercostal muscles, and the upper part of the Serratus anterior. On the *lateral side*, where the anterior and posterior walls converge, the space is narrow, and is bounded by the humerus, the Coraco-brachialis and the Biceps.

The axilla contains the axillary vessels, the infraclavicular part of the brachial plexus of nerves, with its branches, the lateral branches of some of the intercostal nerves, and a large number of lymph glands, together with a quantity of fat and loose areolar tissue. The axillary vessels and the brachial plexus of nerves run from the apex to the base along the lateral wall of the axilla; they are placed nearer to the anterior than to the posterior wall, the axillary vein lying to the thoracic side of the axillary artery and partially concealing it. The thoracic branches of the axillary artery are in contact with the Pectoral muscles, and along the lower margin of the Pectoralis minor the lateral thoracic artery passes to the side of the thorax. The subscapular vessels descend on the posterior wall in contact with the lower margin of the Subscapularis, and the subscapular nerves and the nerve to Latissimus dorsi cross the anterior surface of the muscle with different degrees of obliquity; the circumflex scapular vessels wind round the lateral (axillary) border of the scapula, and the posterior circumflex humeral vessels and the circumflex (axillary) nerve curve backwards close to the surgical neck of the humerus. No vessel of any importance lies on the medial or thoracic side, the upper part of the space being crossed merely by a few small branches from the superior thoracic artery. The nerve to Serratus anterior (long thoracic nerve) descends on the surface of the muscle which it supplies; and the intercostobrachial nerve perforates the upper and anterior part of this wall, and passes across the axilla to the medial side of the upper arm.

The position and arrangement of the lymph glands are described on pp. 858 and 859.

Applied Anatomy.—Penetrating wounds in the axilla are sometimes accompanied by extensive hæmorrhage, either from wound of the main vessels, or of one of the large branches of the axillary artery, e.g. the lateral thoracic or the subscapular. Where the blood cannot find an easy exit it collects in the space and forms a large swelling which projects in the floor of the axilla and also bulges forwards the Pectoralis major. The treatment consists in freely opening up the cavity, searching for and securing the bleeding vessel.

When suppuration occurs in the axilla, the arrangement of the fasciæ plays a very important part in the direction which the pus takes. As described on p. 588, the clavipectoral fascia, after covering the space between the clavicle and the upper border of the Pectoralis minor, splits to enclose this muscle, and at its lower border is incorporated with the axillary fascia at the anterior fold of the axilla. Suppuration may take place either superficial or deep to this layer of fascia; that is, either between the Pectoral muscles or behind the Pectoralis minor; in the former case, the abscess would point either at the border of the anterior axillary fold, or in the groove between the Deltoid and the Pectoralis major; in the latter, the pus would have a tendency to surround the vessels and nerves, and ascend into the neck, that being the direction in which there is least resistance. Its progress towards the surface is prevented by the axillary fascia; its progress backwards,

by the insertion of the Serratus anterior; forwards, by the clavipectoral fascia; medially, by the wall of the thorax; and laterally by the upper limb. The pus in these cases, after extending into the neck, has been known to spread through the superior opening of the thorax into the mediastinum. Instances have been recorded where the pus found its way along the vessels into the upper arm.

When an axillary abscess is opened, the knife should be entered in the floor of the axilla, midway between the anterior and posterior margins and near the thoracic side of the space so as to avoid the lateral thoracic, subscapular, and axillary vessels which are in contact respectively with the anterior, posterior and lateral walls of the axilla.

The relations of the vessels and nerves in the several parts of the axilla are important, for it is the universal procedure to remove the lymph glands from the axilla in operating for cancer of the breast. When such an operation is performed, it is necessary to proceed with much caution in the direction of the lateral wall and apex of the space, as here the axillary vessels are in danger of being wounded.

The Axillary Artery (fig. 723)

The **axillary artery**, the continuation of the subclavian artery, begins at the outer border of the first rib, and ends at the lower border of the Teres major, beyond which the artery takes the name of brachial. Its direction varies with the position of the limb: thus the vessel is nearly straight when the arm is directed at right angles with the trunk, concave upwards when the arm is elevated above the shoulder, and convex upwards and laterally when the arm lies by the side of the trunk. The first part of the artery is deeply situated, but its terminal part is superficial and is covered only by the skin and fasciæ. The Pectoralis minor crosses the vessel and divides it into three portions; the first part is proximal, the second posterior, and the third distal, to the muscle.

Relations of the first part.—*In front* the first part of the axillary artery is covered by the skin, superficial fascia, Platysma, supraclavicular nerves from the cervical plexus, deep fascia, clavicular fibres of the Pectoralis major and the clavipectoral fascia. This part of the artery is crossed by the lateral pectoral (lateral anterior thoracic) nerve, the loop of communication between it and the medial pectoral nerve, and by the acromiothoracic and cephalic veins. *Behind*, the artery is related to the first intercostal space and External intercostal muscle, the first and second digitations of the Serratus anterior, the nerve to Serratus anterior and medial pectoral nerve, and the medial cord of the brachial plexus. On the *lateral side* it is related to the lateral and posterior cords of the brachial plexus; on the *medial side*, to the axillary vein, by which it is overlapped. The first part of the artery is enclosed, together with the axillary vein and the brachial plexus, in a fibrous sheath, termed the *axillary sheath*, continuous above with the prevertebral layer of the deep cervical fascia.

Relations of the second part.—*In front*, the second part of the axillary artery is related to the skin, superficial and deep fascia, and the Pectoralis major and minor; *behind*, to the posterior cord of the brachial plexus and some areolar tissue, which intervene between it and the Subscapularis; on the *medial side*, to the axillary vein, separated from it by the medial cord of the brachial plexus and the medial pectoral nerve; on the *lateral side*, to the lateral cord of the brachial plexus, which separates it from the Coracobrachialis muscle. The cords of the brachial plexus thus surround the second part of the artery on three sides, and separate it from direct contact with the vein and adjacent muscles.

Relations of the third part.—The third part of the axillary artery extends from the lower border of the Pectoralis minor to the lower border of the Teres major. Its upper part is covered *in front* by the lower part of the Pectoralis major; its lower part by the skin and fasciæ only. *Behind*, it is related to the lower part of the Subscapularis and the tendons of the Latissimus dorsi and Teres major. On its *lateral side* is the Coracobrachialis, and on its *medial side*, the axillary vein. The nerves of the brachial plexus bear the following relations to this part of the artery; on the *lateral side* are the lateral root and the trunk of the median, and, for a short distance, the musculocutaneous; on the *medial side*, the medial cutaneous nerve of the forearm lies between the axillary artery and vein anteriorly, and the ulnar nerve between the artery and vein posteriorly;

the medial cutaneous nerve of the upper arm is on the medial side of the vein; *in front* is the medial root of the median nerve, and *behind*, the radial and circumflex nerves, the latter only as far as the lower border of the Subscapularis.

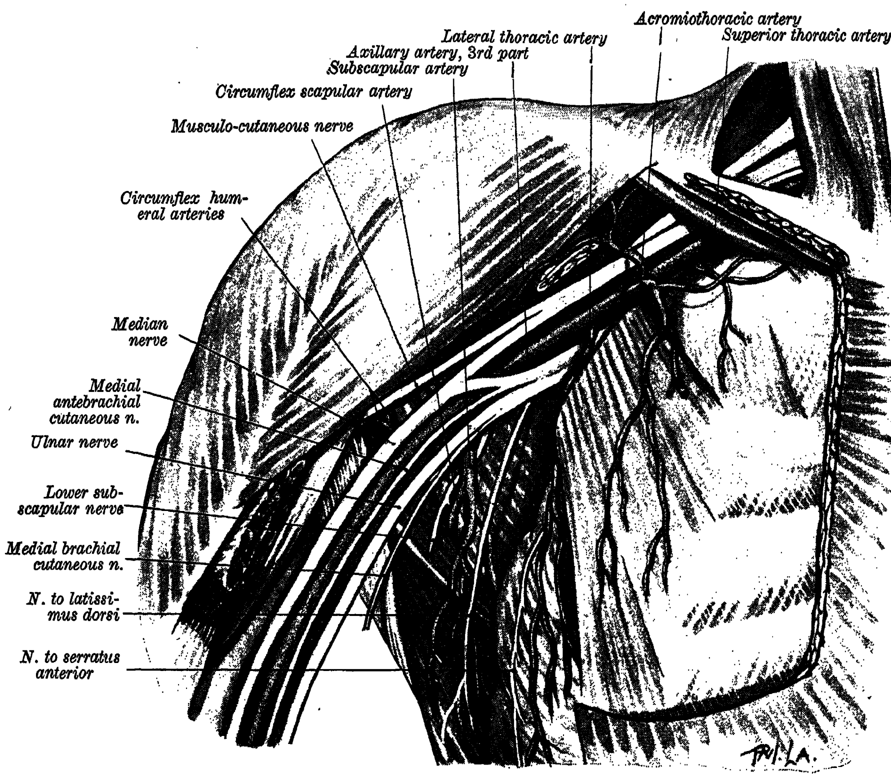
The branches of the axillary artery are :

From first part. 1. Superior thoracic. *From second part* { 2. Acromiothoracic. 3. Lateral thoracic.

From third part { 4. Subscapular. 5. Anterior circumflex humeral. 6. Posterior circumflex humeral.

1. The **superior thoracic artery** (fig. 723) is a small vessel which arises from the axillary artery near the lower border of the Subclavius muscle, but it may

Fig. 723.—The right axillary artery and its branches. The Pectoralis major has been removed and a portion of the Pectoralis minor has been excised.



take origin from the acromiothoracic artery. Running forwards and medially along the upper border of the Pectoralis minor, it passes between it and the Pectoralis major to the side of the chest. It supplies branches to these muscles, and to the thoracic wall, and anastomoses with the internal mammary and intercostal arteries.

2. The **acromiothoracic artery** (fig. 723) is a short trunk which arises from the front of the axillary artery, its origin being overlapped by the upper edge of the Pectoralis minor. Passing forwards round the upper border of this muscle, it pierces the clavipectoral fascia and divides into four branches—pectoral, acromial, clavicular and deltoid. The *pectoral branch* descends between the two Pectoral muscles, and is distributed to them and to the breast, anastomosing with the intercostal branches of the internal mammary artery and with the lateral thoracic artery. The *acromial branch* runs laterally over the coracoid process and under the Deltoid, to which it gives branches; it then pierces that muscle and ends on the acromion, where it anastomoses with the branches of the suprascapular (transverse scapular), acromiothoracic and

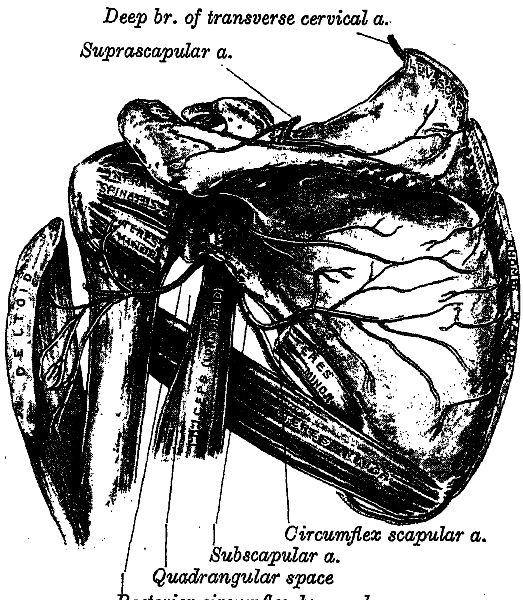
posterior circumflex humeral arteries. The *clavicular branch* runs upwards and medially between the clavicular part of the Pectoralis major and the clavipectoral fascia; it gives branches to the sternoclavicular joint, and to the Subclavius. The *deltoid*, or *humeral*, *branch* often arises with the acromial branch; it crosses over the Pectoralis minor and runs with the cephalic vein in the interval between the Pectoralis major and Deltoid, giving branches to both muscles.

3. The **lateral thoracic artery** (fig. 723) follows the lower border of the Pectoralis minor to the side of the chest, supplies the Serratus anterior and the Pectoral muscles, and sends branches to the axillary lymph glands, and to the Subscapularis; it anastomoses with the internal mammary, subscapular, and intercostal arteries, and with the pectoral branch of the acromiothoracic artery. In the female, the lateral thoracic artery is large, and gives off an *external mammary branch*, which turns round the lower border of the Pectoralis major and supplies the mamma.

4. The **subscapular artery** (fig. 723) is the largest branch of the axillary artery; usually it arises at the lower border of the Subscapularis, which it follows to the inferior angle of the scapula, where it anastomoses with the lateral thoracic and intercostal arteries and with the deep branch of the transverse cervical artery; finally it ends in the neighbouring muscles and adjacent part of the chest-wall. In the lower part of its course it is accompanied by the nerve to the Latissimus dorsi; about 4 cm. from its origin it gives off the *circumflex scapular artery*.

The **circumflex scapular artery** is generally larger than the continuation of the subscapular. It curves round the lateral border of the scapula, traversing the triangular space between the Subscapularis above, the Teres major below, and the long head of the Triceps laterally (fig. 724); it enters the infraspinous fossa under cover of the Teres minor, and anastomoses with the suprascapular artery and the deep branch of the transverse cervical artery. It gives off two branches: one (*infrascapular*) enters the subscapular fossa deep to the Subscapularis, which it supplies, and anastomoses with the suprascapular artery and the deep branch of the transverse cervical artery; the other is continued along the lateral border of the scapula, between the Teres major and the Teres minor, and at the dorsal surface of the inferior angle anastomoses with the deep branch of the transverse cervical artery. In addition, small branches are distributed to the posterior part of the Deltoid and the long head of the Triceps, and anastomose with an ascending branch of the arteria profunda brachii.

FIG. 724.—The scapular anastomosis of the left side; dorsal aspect.



5. The **anterior circumflex humeral artery** (fig. 724) is a small artery which arises from the lateral side of the axillary artery at the lower border of the Subscapularis. It runs horizontally, behind the Coracobrachialis and short head of the Biceps, in front of the surgical neck of the humerus. On reaching the bicipital groove (intertubercular sulcus), it gives off a branch which ascends in it to supply the head of the humerus and the shoulder-joint. The artery is then continued laterally under cover of the long head of the

Biceps and the Deltoid, and anastomoses with the posterior circumflex humeral artery.

6. **The posterior circumflex humeral artery** (fig. 724) is considerably larger than the anterior. It arises from the axillary artery at the lower border of the Subscapularis, and runs backwards with the circumflex (axillary) nerve through the quadrangular space, which is bounded by the Subscapularis, the capsule of the shoulder-joint and the Teres minor above, the Teres major below, the long head of the Triceps medially, and the surgical neck of the humerus laterally. It winds round the neck of the humerus and distributes branches to the shoulder-joint, the Deltoid, the Teres major and minor, and the long and lateral heads of the Triceps, and gives off a descending branch which anastomoses with the arteria profunda brachii. It also anastomoses with the anterior circumflex humeral, suprascapular and acromiothoracic arteries.

Peculiarities.—The branches of the axillary artery vary considerably in different subjects. One, named *alar thoracic*, and frequently derived from the second part of the artery, is distributed to the fat and the lymph glands in the axilla. Occasionally the subscapular, circumflex humeral and profunda arteries arise from a common trunk, and when this occurs the branches of the brachial plexus surround this trunk instead of the main vessel. The posterior circumflex humeral artery may arise from the arteria profunda brachii; it then passes backwards below the Teres major, instead of accompanying the circumflex nerve through the quadrangular space. Sometimes the axillary artery divides into the radial and ulnar arteries, and occasionally it gives origin to the anterior interosseous artery of the forearm.

Applied Anatomy.—Compression of the axillary artery may be required in the removal of tumours, or in amputation of the upper part of the arm. The only situation in which compression can be effectually made is in the lower part of its course; by pressing the artery against the humerus in this situation the circulation may be effectually arrested.

With the exception of the popliteal, the axillary artery is perhaps more frequently lacerated than any other artery in the body by violent movements, particularly in those cases where its coats are diseased. It has occasionally been ruptured in attempts to reduce old dislocations of the shoulder-joint, especially where the artery has become fixed to the capsule of the joint.

Collateral Circulation.—If the axillary artery be tied above the origin of the acromiothoracic artery, the collateral circulation will be carried on by the same branches as after the ligature of the third part of the subclavian (p. 733); if at a lower point, between the acromiothoracic and the subscapular arteries, the latter vessel, by its free anastomoses with the suprascapular and transverse cervical arteries, will become the chief agent in carrying on the circulation; the lateral thoracic artery, if it be below the ligature, will materially contribute by its anastomoses with the intercostal and internal mammary arteries. If the ligature be applied below the origin of the subscapular artery, it will most probably also be below the origins of the two circumflex humeral arteries; the chief agents in restoring the circulation will then be the subscapular and the two circumflex humeral arteries through anastomoses with the arteria profunda brachii.

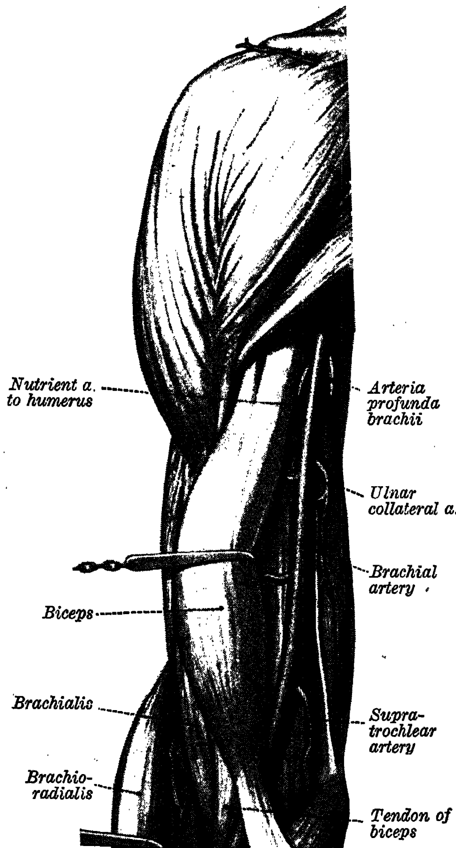
The Brachial Artery (figs. 725, 726, 727)

The **brachial artery** is a continuation of the axillary artery. It begins at the lower border of the tendon of the Teres major, runs down the arm, and ends about 1 cm. below the elbow-joint by dividing into radial and ulnar arteries. At first it lies on the medial side of the humerus, but, largely owing to the inclination of the humerus, it gradually passes to the front of the upper arm and is placed midway between the humeral epicondyles at the elbow.

Relations.—The artery is superficial throughout its entire extent, being covered with the skin and the superficial and deep fasciæ; the bicipital aponeurosis (lacertus fibrosus) lies in front of it opposite the elbow and separates it from the median cubital vein; the median nerve crosses the artery from the lateral to the medial side opposite the insertion of the Coracobrachialis. *Posteriorly* it lies at first on the long head of the Triceps separated by the radial nerve and the profunda brachii artery. It then lies successively on the medial head of the Triceps, the insertion of the Coracobrachialis, and the Brachialis. *Laterally*, it is in relation above with the median nerve and the Coracobrachialis,

below with the Biceps, the two muscles overlapping the artery to some extent. *Medially*, its upper half is in relation with the medial antebrachial cutaneous and ulnar nerves, its lower half with the median nerve. The basilic vein lies on its medial side, but is separated from it in the lower part of the upper arm by the deep fascia. The artery is closely accompanied by two venæ comitantes, which are connected at intervals by short transverse branches.

FIG. 725.—The right brachial artery.



THE CUBITAL FOSSA

At the bend of the elbow the brachial artery sinks deeply into a triangular interval, which is named the *cubital fossa*. The base of the triangle is represented by a line connecting the two humeral epicondyles; the sides are formed by the medial edge of the Brachioradialis and the lateral margin of the Pronator teres; the floor consists of the Brachialis and Supinator. This fossa contains the tendon of the Biceps, the terminal part of the brachial artery, and its accompanying veins, the origins of the radial and ulnar arteries, and parts of the median and radial nerves. The brachial artery occupies the middle of the fossa, and divides opposite the neck of the radius into the radial and ulnar arteries; it is covered, *in front*, by the skin, the superficial fascia, and the median cubital vein, the last being separated from the artery by the bicipital aponeurosis (lacertus fibrosus). *Behind*, the Brachialis separates it from the elbow-joint. The median nerve lies close to the medial side of the artery above, but is separated from its ulnar branch below by the ulnar head of the Pronator teres. The tendon of the Biceps is lateral to the artery; the radial nerve rests upon the Supinator, and is concealed by the Brachioradialis.

Peculiarities.—The brachial artery, accompanied by the median nerve, may leave the medial border of the Biceps, and descend towards the medial epicondyle of the humerus; in such cases it usually passes behind the *supracondylar process* of the humerus, from which a fibrous arch is in most cases thrown over the artery; it then runs behind or through the substance of the Pronator teres, to the bend of the elbow. This variation bears considerable analogy with the normal condition of the artery in some of the carnivora, and has been referred to in the description of the humerus (p. 346). Occasionally, the upper part of the artery splits into two trunks which reunite. Frequently it divides at a higher level than usual, and the vessels concerned in this high division are three: viz. radial, ulnar and interosseous arteries. Most frequently the radial is given off high up, the other limb of the division consisting of the ulnar and interosseous; in some instances the ulnar originates above the ordinary level, and the radial and interosseous form the other limb of the division; occasionally the interosseous arises high up.

Sometimes long, slender vessels, termed *vasa aberrantia,* connect the brachial or the axillary artery with one or other of the arteries of the forearm. These vessels usually join the radial.

FIG. 726.—A transverse section through the arm at the junction of the proximal with the intermediate one-third of the humerus.

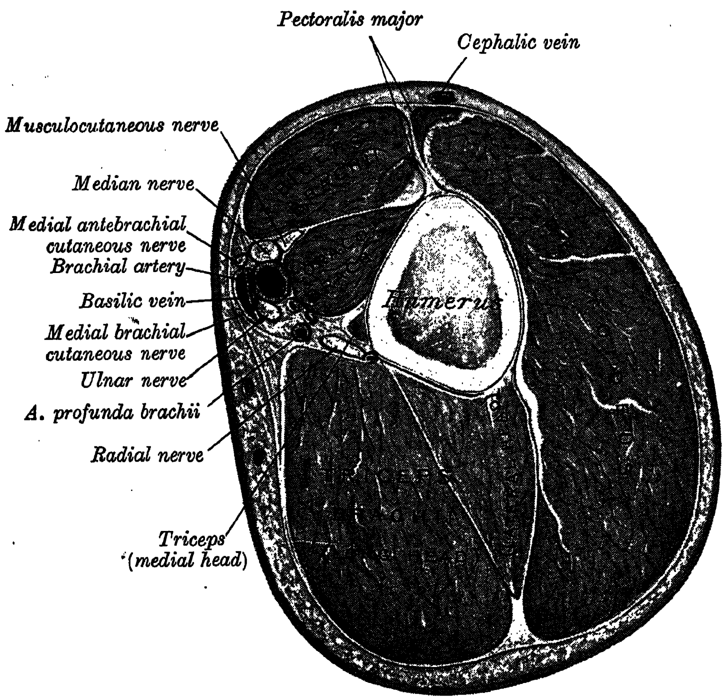
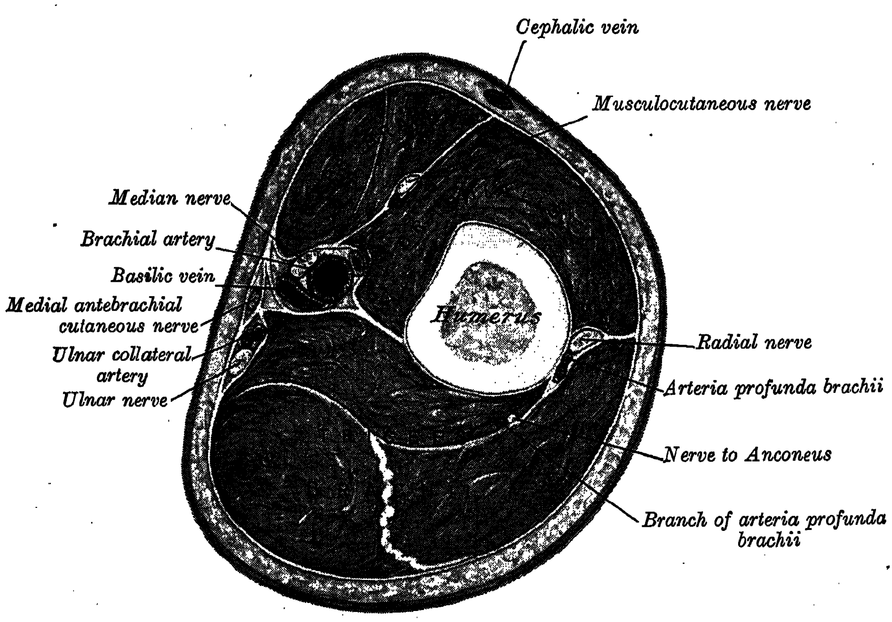


FIG. 727.—A transverse section through the arm, a little below the middle of the body of the humerus.



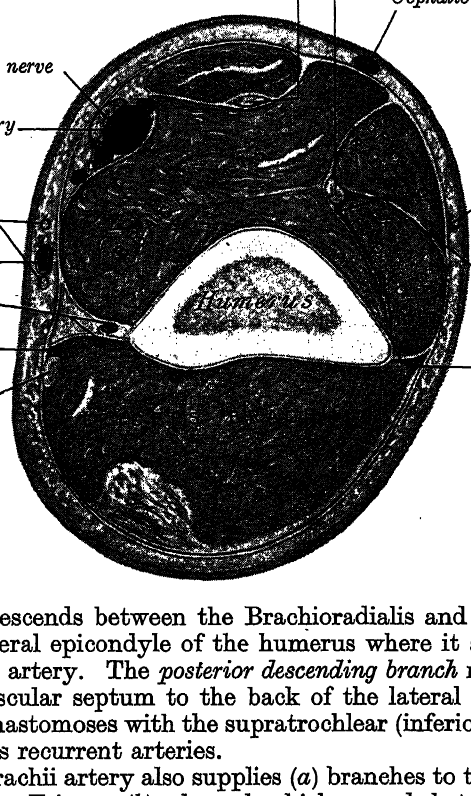
The brachial artery is occasionally concealed in some part of its course, by muscular or tendinous slips derived from the Coracobrachialis, Biceps, Brachialis or Pronator teres.

The branches of the brachial artery are:

1. Profunda brachii.
2. Nutrient.
3. Ulnar collateral.
4. Supratrochlear.
5. Muscular.

1. The **profunda brachii artery** (figs. 725, 726) is a large vessel which arises from the medial and posterior part of the brachial artery, just below the lower border of the Teres major. It follows the radial nerve closely, running at first backwards between the long and medial heads of the Triceps, then along the spiral groove (sulcus for the radial nerve), where it is covered by the lateral head of the Triceps. Reaching the lateral side of the arm, it divides into anterior and posterior descending branches. The *anterior descending branch*, which is usually the smaller, pierces the lateral intermuscular septum with the

FIG. 728.—A transverse section through the arm, 2 cm. above the medial epicondyle of the humerus.



radial nerve, and descends between the Brachioradialis and the Brachialis to the front of the lateral epicondyle of the humerus where it anastomoses with the radial recurrent artery. The *posterior descending branch* runs down behind the lateral intermuscular septum to the back of the lateral epicondyle of the humerus where it anastomoses with the supratrochlear (inferior ulnar collateral) and the interosseous recurrent arteries.

The profunda brachii artery also supplies (*a*) branehes to the Deltoid and to the three heads of the Triceps, (*b*) a branch which ascends between the long and lateral heads of the Triceps and anastomoses with the posterior circumflex humeral artery, and (*c*) a collateral twig which descends in the medial head of the Triceps with the nerve to the Anconeus, and takes part in the anastomosis above the olecranon. Sometimes the profunda brachii artery supplies a *nutrient artery* to the humerus, which enters the bone behind the deltoid tuberosity.

2. The **nutrient artery** of the humerus arises usually about the middle of the upper arm; it enters the nutrient canal near the insertion of the Coracobrachialis, and is directed downwards.

3. The **ulnar collateral artery** (superior ulnar collateral artery) (figs. 725, 727) is a small vessel which arises from the brachial a little below the middle of the upper arm; it frequently springs from the upper part of the arteria

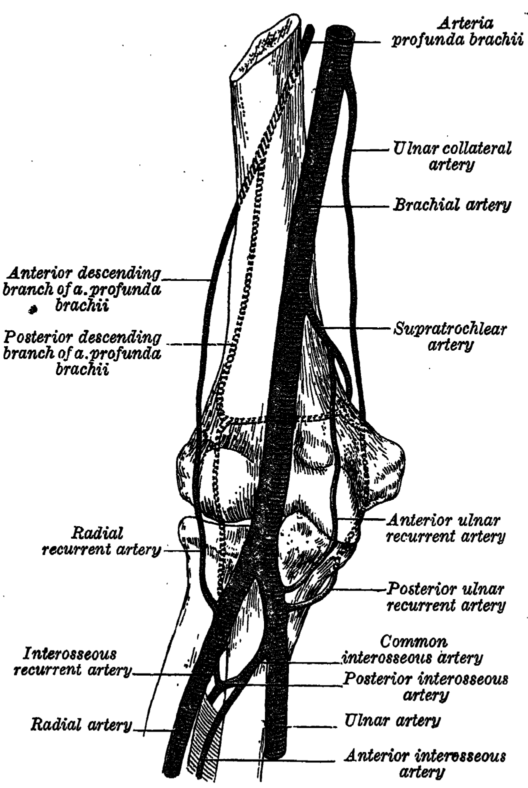
profunda brachii. It accompanies the ulnar nerve, pierces the medial intermuscular septum, descends between the medial epicondyle and the olecranon, and ends under cover of the Flexor carpi ulnaris by anastomosing with the posterior ulnar recurrent and supratrochlear arteries. It sometimes sends a branch in front of the medial epicondyle, to anastomose with the anterior ulnar recurrent artery.

4. The **supratrochlear artery** (inferior ulnar collateral artery) (figs. 725, 728) arises about 5 cm. above the elbow. It passes medially behind the median nerve and upon the Brachialis and, piercing the medial intermuscular septum, winds round the back of the humerus between the Triceps and the bone, forming, by its junction with the posterior descending branch of the arteria profunda brachii, an arch above the olecranon fossa. As the vessel lies on the Brachialis, it gives off branches which ascend to join the ulnar collateral artery; others descend in front of the medial epicondyle, to anastomose with the anterior ulnar recurrent artery. Behind the medial epicondyle a branch anastomoses with the ulnar collateral and posterior ulnar recurrent arteries.

5. The **muscular branches**, three or four in number, are distributed to the Coracobrachialis, Biceps and Brachialis.

The anastomosis around the elbow-joint (fig. 729).—The vessels engaged in this anastomosis may be conveniently divided into those *in front* of the medial and lateral epicondyles of the humerus and those *behind*. The branches anastomosing *in front* of the medial epicondyle are: the anterior branches of the ulnar collateral, and supratrochlear and the anterior ulnar recurrent artery. Those anastomosing *behind* the medial epicondyle are: the ulnar collateral, the supratrochlear and the posterior ulnar recurrent artery. The branches anastomosing *in front* of the lateral epicondyle are: the anterior descending branch of the profunda brachii artery, and the radial recurrent artery. Those anastomosing *behind* the lateral epicondyle are: the posterior descending branch of the profunda brachii artery and the interosseous recurrent artery. There is also an arch of anastomosis above the olecranon fossa formed by the supratrochlear artery joining with the posterior descending branch of the arteria profunda brachii, and with the interosseous recurrent and the posterior ulnar recurrent arteries (fig. 729).

FIG. 729.—A diagram of the arterial anastomosis around the elbow-joint.



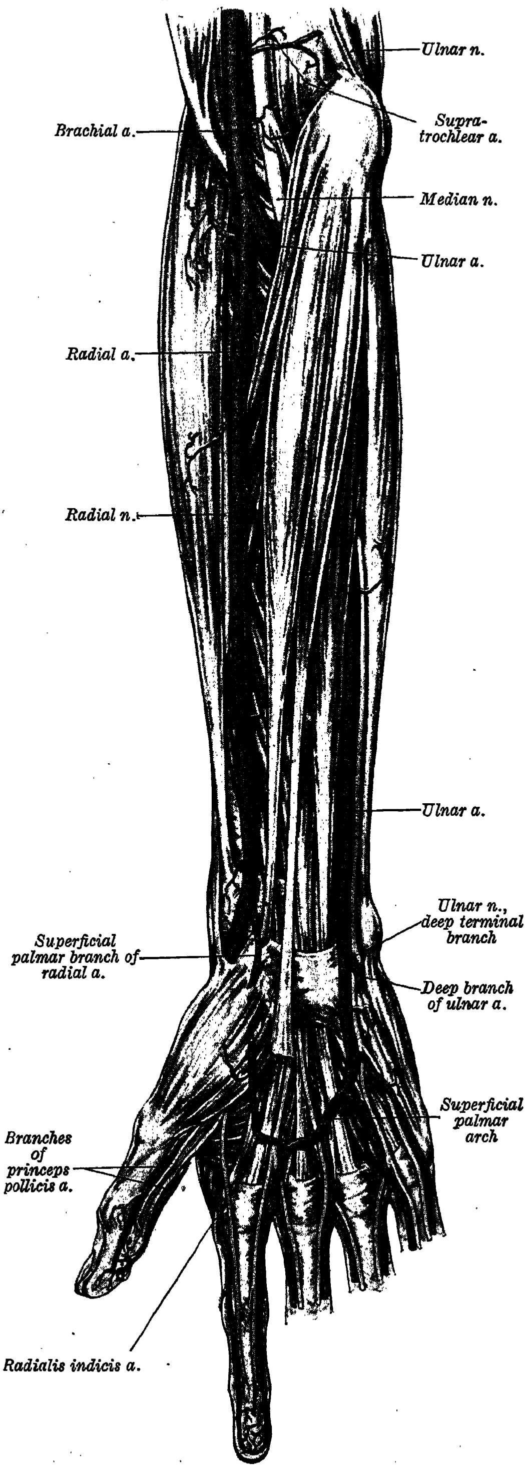
Applied Anatomy.—In spite of the fact that the brachial artery is very superficial and but little protected by surrounding parts, it is seldom wounded. This, no doubt, is due to its situation on the medial side of the upper arm, which is little exposed to injury.

Compression of the brachial artery is required in case of amputation and some other operations in the upper arm and forearm, and may be effected in almost any part of the course of the artery. If pressure be made in the upper part of the upper arm, it should be directed laterally; if in the lower part, backwards, as the artery lies on the medial side of the humerus above, and in front of it below. The most favourable situation is about the middle of the arm, where the artery lies on the tendon of the Coracobrachialis on the medial surface of the humerus.

Collateral Circulation.—After the application of a ligature to the brachial artery in the upper third of the upper arm, the circulation is carried on by branches from the circumflex

humeral and subscapular arteries anastomosing with ascending branches from the arteria profunda brachii. If the artery be tied below the origins of the arteria profunda brachii and ulnar collateral artery, the circulation is maintained through the anastomoses around the elbow-joint (p. 748).

Fig. 730.—The right radial and ulnar arteries. Superficial dissection.



The Radial Artery (figs. 730, 731, 733)

The **radial artery**, though smaller than the ulnar artery, appears, from its course, to be the more direct continuation of the brachial trunk. It begins at the division of the brachial, about 1 cm. below the bend of the elbow, and passes along the radial side of the forearm to the wrist. It then winds backwards, round the lateral side of the carpus, under cover of the tendons of the Abductor pollicis longus and Extensores pollicis brevis et longus to the proximal end of the space between the first and second metacarpal bones where it passes forwards between the two heads of the first Dorsal interosseous muscle, into the palm of the hand; it crosses towards the ulnar side of the palm, and forms the deep palmar arch by uniting with the deep branch of the ulnar artery. The radial artery is therefore divisible into three portions, one in the forearm, a second at the wrist, and a third in the hand.

Relations.—(*a*) *In the forearm* (figs. 730, 731, 732, 734), the radial artery extends from the neck of the radius to the front part of its styloid process, being placed to the medial side of the shaft of the bone above, and in front of it below. Its upper part is overlapped by the fleshy belly of the Brachioradialis; the rest of the artery is covered only with the skin, and the superficial and deep fasciæ. It lies successively upon the tendon of the Biceps, the Supinator, the insertion of the Pronator teres, the radial origin of the Flexor digitorum sublimis, the Flexor pollicis longus, the Pronator quadratus and the lower end of the radius. The Pronator teres is medial, and the Brachioradialis lateral, to the upper one-third of the artery; the tendon of the Flexor carpi radialis is medial, and the tendon of the Brachioradialis lateral to its

lower two-thirds. The radial nerve (superficial branch) is close to the lateral side of the middle one-third of the vessels; and some filaments of the lateral cutaneous nerve of the forearm run along the lower part of the artery as it winds round the wrist. Throughout its course the vessel is accompanied by a pair of venæ comitantes. The portion of the radial artery which lies in front of the lower end of the radius and on the lateral side of the tendon of the Flexor carpi radialis is used clinically for observations on the pulse.

(*b*) *At the wrist* (figs. 734, 736), the radial artery reaches the back of the carpus by passing between the lateral ligaments of the wrist and the tendons of the Abductor pollicis longus and Extensor pollicis brevis. It then descends on the scaphoid bone and the trapezium (os multangulum majus), and before disappearing between the heads of the first Dorsal interosseous muscle is crossed by the tendon of the Extensor pollicis longus. In the interval between the two Extensores pollicis it is crossed by the origin of the cephalic vein, and by the digital branches of the radial nerve which go to the thumb and index finger.

(*c*) *In the hand* (fig. 732), the radial artery passes from the proximal end of the first interosseous space, between the heads of the first Dorsal interosseous muscle, transversely across the palm; it lies at first deep to the oblique head of the Adductor pollicis, then runs between the oblique and transverse heads, or through the transverse head, of that muscle. At the base of the fifth metacarpal bone it anastomoses with the deep branch from the ulnar artery, and so completes the *deep palmar arch* (fig. 732).

Peculiarities.—In about 12 per cent. of subjects the origin of the radial artery is higher than usual; it then arises more often from the axillary or upper part of the brachial artery than from the lower part of the latter vessel. In the forearm it sometimes lies on the deep fascia instead of beneath it, and on the surface of the Brachioradialis instead of under cover of its medial border; in turning round the wrist, it occasionally lies on, instead of deep to, the extensor tendons of the thumb.

The branches of the radial artery may be divided into three groups, corresponding with the three regions in which the vessel is situated.

In the forearm.	*At the wrist.*	*In the hand.*
Radial recurrent.	Posterior carpal.	Princeps pollicis.
Muscular.	First dorsal metacarpal.	Radialis indicis.
Anterior carpal.		
Superficial palmar.		

The **radial recurrent artery** arises immediately below the elbow. It passes between the radial nerve and its posterior interosseous branch, and ascends under cover of the Brachioradialis, lying on the Supinator and Brachialis; it supplies these muscles and the elbow-joint, and anastomoses with the anterior descending branch of the arteria profunda brachii.

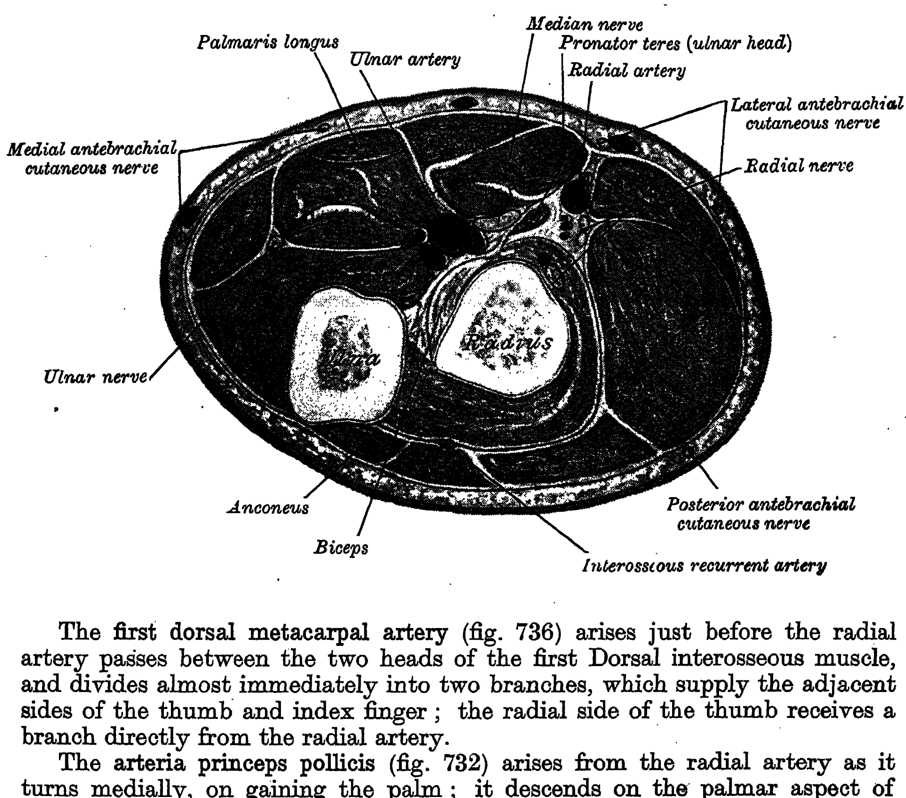
The **muscular branches** are distributed to the muscles on the radial side of the forearm.

The **anterior carpal branch** is a small vessel which arises near the lower border of the Pronator quadratus, and, running medially across the anterior surface of the carpus, anastomoses under cover of the flexor tendons with the anterior carpal branch of the ulnar artery. This anastomosis is joined by a branch from the anterior interosseous artery, and by recurrent branches from the deep palmar arch, thus forming an *anterior carpal arch*, which supplies the articulations of the wrist and carpus.

The **superficial palmar branch** (fig. 730) arises from the radial artery where this vessel is about to wind round the lateral side of the wrist. It passes through, occasionally over, the muscles of the ball of the thumb, which it supplies, and sometimes anastomoses with the terminal portion of the ulnar artery, completing the superficial palmar arch. This vessel varies considerably in size: usually it is very small, and ends in the muscles of the thumb; sometimes it is as large as the continuation of the radial artery.

The **posterior carpal branch** (fig. 736) is a small vessel which arises deep to the extensor tendons of the thumb, and, running medially across the posterior surface of the carpus under cover of the extensor tendons, anastomoses with the posterior carpal branch of the ulnar artery, and with the anterior and posterior interosseous arteries, to form a *posterior carpal arch*. Arising from this arch, three slender *dorsal metacarpal arteries* descend on the second, third and fourth Dorsal interosseous muscles and bifurcate into dorsal digital branches for the supply of the adjacent sides of the index, middle, ring and little fingers; they anastomose with the palmar digital branches of the superficial palmar arch; near their origins they anastomose with the deep palmar arch by the *superior perforating arteries*, and, near their points of bifurcation, with the palmar digital vessels of the superficial palmar arch by the *inferior perforating arteries*.

FIG. 731.—A transverse section through the forearm at the level of the radial tuberosity.



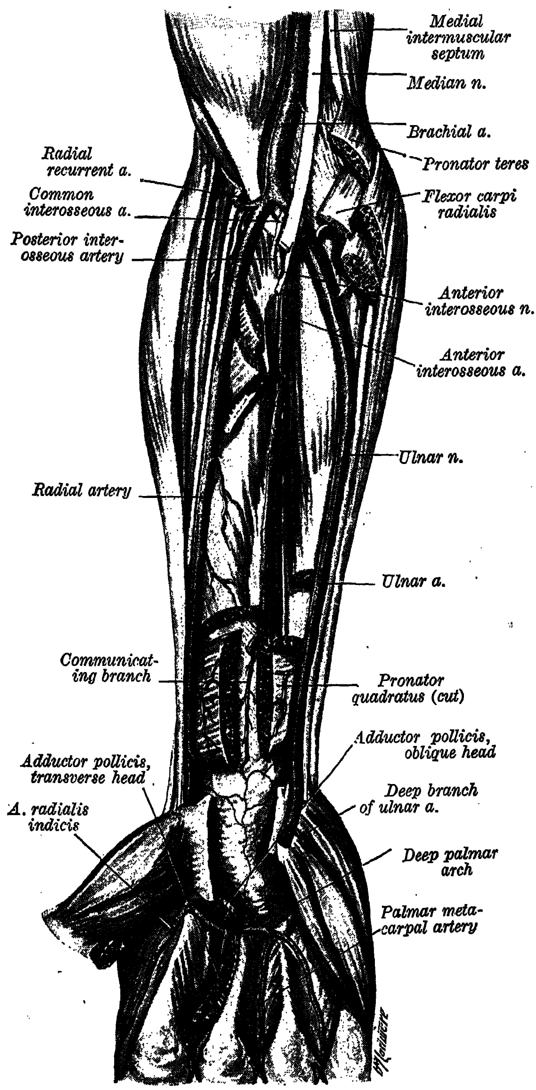
The **first dorsal metacarpal artery** (fig. 736) arises just before the radial artery passes between the two heads of the first Dorsal interosseous muscle, and divides almost immediately into two branches, which supply the adjacent sides of the thumb and index finger; the radial side of the thumb receives a branch directly from the radial artery.

The **arteria princeps pollicis** (fig. 732) arises from the radial artery as it turns medially, on gaining the palm; it descends on the palmar aspect of the first metacarpal bone under cover of the oblique head of the Adductor pollicis and lateral to the first palmar interosseous muscle (deep head of the Flexor pollicis brevis). At the base of the proximal phalanx, where it lies behind the tendon of the Flexor pollicis longus, it divides into two branches. These make their appearance between the medial and lateral insertions of the oblique head of the Adductor pollicis, and run along the sides of the thumb, forming on the palmar surface of the distal phalanx an arch, from which branches are distributed to the skin and subcutaneous tissue of the thumb.

The **arteria radialis indicis** (fig. 732), which frequently arises from the proximal part of the arteria princeps pollicis, descends between the first Dorsal interosseous and the transverse head of the Adductor pollicis, and runs along the lateral side of the index finger to its extremity: it anastomoses with the digital artery supplying the medial side of the finger. At the

lower border of the transverse head of the Adductor pollicis this vessel anastomoses with the arteria princeps pollicis, and gives a communicating branch to the superficial palmar arch.

Fig. 732.—The arteries of the forearm and hand. Deep dissection.



The arteria princeps pollicis and arteria radialis indicis may spring from a common trunk, which is named the *first palmar metacarpal artery*.

The **deep palmar arch** (fig. 732) is formed by the anastomosis of the terminal part of the radial artery with the deep branch of the ulnar artery. It lies upon the proximal ends of the metacarpal bones and on the Interossei, and is covered by the oblique head of the Adductor pollicis, the flexor tendons of the fingers and the Lumbrical muscles. In its concavity, but running towards the lateral side of the hand, is the deep branch of the ulnar nerve.

The branches of the deep palmar arch are: palmar metacarpal, perforating and recurrent.

The **palmar metacarpal arteries** (fig. 732), three in number, arise from the convexity of the deep palmar arch; they run distally upon the Interossei of the second, third and fourth spaces, and, at the clefts of the fingers, join the digital branches of the superficial palmar arch.

The **perforating branches**, three in number, pass backwards from the deep palmar arch, through the second, third and fourth interosseous spaces and between the heads of the corresponding Dorsal interosseous muscles, to anastomose with the dorsal metacarpal arteries.

The **recurrent branches** arise from the concavity of the deep palmar arch; they ascend in front of the wrist, supply the intercarpal articulations, and end in the anterior carpal arch.

The Ulnar Artery (figs. 730 to 735)

The **ulnar artery**, the larger of the two terminal branches of the brachial artery, begins opposite to the neck of the radius, about 1 cm. below the bend of the elbow, and, passing downwards and medially, reaches the medial side of the forearm at a point about midway between the elbow and the wrist. It then runs along the medial side of the forearm to the wrist, and crosses the flexor retinaculum (transverse carpal ligament) on the lateral side of the ulnar nerve and the pisiform bone. Immediately beyond this bone it gives off a deep branch, and is then continued across the palm under the name of the superficial palmar arch.

Relations.—(*a*) *In the forearm.*—The *upper half* of the vessel (figs. 730, 731, 732) is deeply seated, passing obliquely under cover of the Pronator teres, Flexor carpi radialis, Palmaris longus and Flexor digitorum sublimis to the medial side of the forearm, where it is overlapped by the Flexor carpi ulnaris; it lies upon the Brachialis and the Flexor digitorum profundus. Below the elbow the median nerve is on the medial side of the artery for about 2·5 cm. and then crosses the vessel, but is separated from it by the ulnar head of the Pronator teres. The *lower half* of the vessel (figs. 730, 735) lies upon the Flexor digitorum profundus; it is covered by the skin, superficial and deep fasciæ, and is placed between the Flexor carpi ulnaris and Flexor digitorum sublimis.

It is accompanied by two venæ comitantes, and is overlapped in its middle one-third by the Flexor carpi ulnaris; the ulnar nerve lies close to the medial side of the lower two-thirds of the artery, and the palmar cutaneous branch of this nerve descends on the lower part of the vessel to the palm of the hand.

(*b*) *At the wrist* (figs. 732, 733, 734) the ulnar artery is covered by the skin and fasciæ and the Palmaris brevis muscle, and lies between the superficial and the main part of the flexor retinaculum (p. 609). The ulnar nerve and the pisiform bone are on its medial side.

Peculiarities.—The ulnar artery varies in its origin in about 8 per cent. of cases; it frequently arises above the elbow, the brachial being more often the source of origin than the axillary. When its origin is normal, the course of the vessel is rarely changed. When the artery arises high up, it is usually superficial to the flexor muscles in the forearm, lying commonly beneath the fascia, more rarely between the fascia and skin; the brachial artery then gives off the common interosseous artery, and the latter, the anterior and posterior ulnar recurrent arteries. Occasionally it is subcutaneous in the upper part of the forearm, and subfascial in the lower part.

When the ulnar artery is superficial there is some danger of its being wounded when the median cubital vein is opened for the purpose of transfusing blood or injecting saline solution.

The branches of the ulnar artery may be arranged in the following groups:

In the forearm	Anterior recurrent. Posterior recurrent. Common interosseous. Muscular.	*At the wrist* *In the hand*	Anterior carpal. Posterior carpal. Deep branch. Superficial palmar arch.

The **anterior ulnar recurrent artery** (figs. 729, 732), a small branch, arises immediately below the elbow-joint, runs upwards between the Brachialis and Pronator teres, supplies twigs to those muscles, and, in front of the medial epicondyle, anastomoses with the ulnar collateral and supratrochlear arteries.

The **posterior ulnar recurrent artery** (figs. 729, 732) is much larger, and arises somewhat lower than the anterior artery. It passes backwards and medially on the Flexor digitorum profundus, behind the Flexor digitorum sublimis, and ascends behind the medial epicondyle of the humerus. In the interval between this process and the olecranon, it lies deep to the Flexor carpi ulnaris, and ascends between the two heads of this muscle, in contact with the ulnar nerve; it supplies the neighbouring muscles and the elbow-joint, and anastomoses with the ulnar collateral, the supratrochlear and the interosseous recurrent arteries (fig. 736).

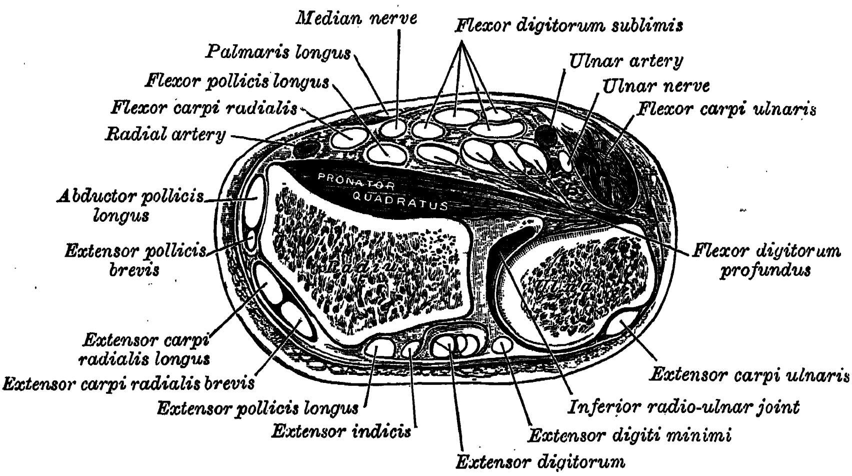
The **common interosseous artery** (fig. 732), about 1 cm. in length, arises immediately below the tuberosity of the radius, and, passing backwards to the upper border of the interosseous membrane of the forearm, divides into two branches, termed the *anterior* and *posterior interosseous arteries*.

The **anterior interosseous artery** (figs. 732, 735) descends on the anterior surface of the interosseous membrane of the forearm, accompanied by the anterior interosseous branch of the median nerve, and overlapped by the contiguous margins of the Flexor digitorum profundus and Flexor pollicis longus; it gives off *muscular* branches, and the *nutrient* arteries of the radius and ulna. At the upper border of the Pronator quadratus it pierces the interosseous membrane and reaches the back of the forearm, where it anastomoses with the

posterior interosseous artery and descends on the back of the wrist in the compartment of the extensor retinaculum (dorsal carpal ligament) containing the tendons of the Extensor digitorum and Extensor indicis, and joins the posterior carpal arch. Before the artery pierces the interosseous membrane, it sends a branch downwards behind the Pronator quadratus to join the anterior carpal arch. The *arteria mediana*, a long, slender branch, arises from the beginning of the anterior interosseous artery, and accompanies the median nerve closely. Sometimes it is much enlarged and runs with the nerve into the palm of the hand (p. 152), where it may join the superficial palmar arch or end as one or two of the palmar digital arteries.

The **posterior interosseous artery** (figs. 735, 736), usually smaller than the anterior interosseous artery, passes backwards between the oblique cord and the upper border of the antebrachial interosseous membrane. It appears on

FIG. 733.—A transverse section through the lower ends of the left radius and ulna. Superior aspect.



the back of the forearm between the contiguous borders of the Supinator and the Abductor pollicis longus, and descends between the superficial and deep layers of muscles, to both of which it distributes branches. As it lies upon the Abductor pollicis longus, it is accompanied by the posterior interosseous nerve (deep branch of the radial nerve). At the lower part of the forearm it anastomoses with the termination of the anterior interosseous artery, and with the posterior carpal arch. It gives off, near its origin, the *interosseous recurrent artery*, which ascends to the interval between the lateral epicondyle and olecranon, on or through the fibres of the Supinator, but deep to the Anconeus, and anastomoses with the posterior descending branch of the arteria profunda brachii, and with the posterior ulnar recurrent, and supratrochlear (inferior ulnar collateral) arteries.

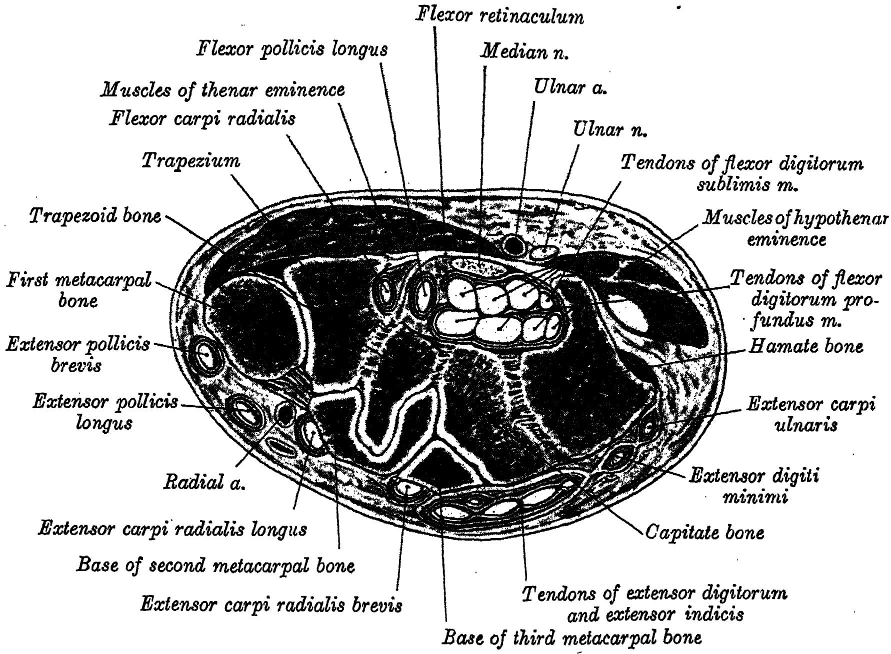
The **muscular branches** are distributed to the muscles along the ulnar side of the forearm.

The **anterior carpal branch** is a small vessel which crosses the front of the carpus behind the tendons of the Flexor digitorum profundus ; it anastomoses with the anterior carpal branch of the radial artery, and assists in forming the anterior carpal arch (p. 750).

The **posterior carpal branch** arises immediately above the pisiform bone, and winds backwards deep to the tendon of the Flexor carpi ulnaris ; it passes laterally across the posterior surface of the carpus under cover of the extensor tendons, anastomoses with the posterior carpal branch of the radial artery, and assists in forming the posterior carpal arch (p. 751). Near to its origin it gives off a small branch which runs along the ulnar side of the fifth metacarpal bone, and supplies the ulnar side of the dorsal surface of the little finger.

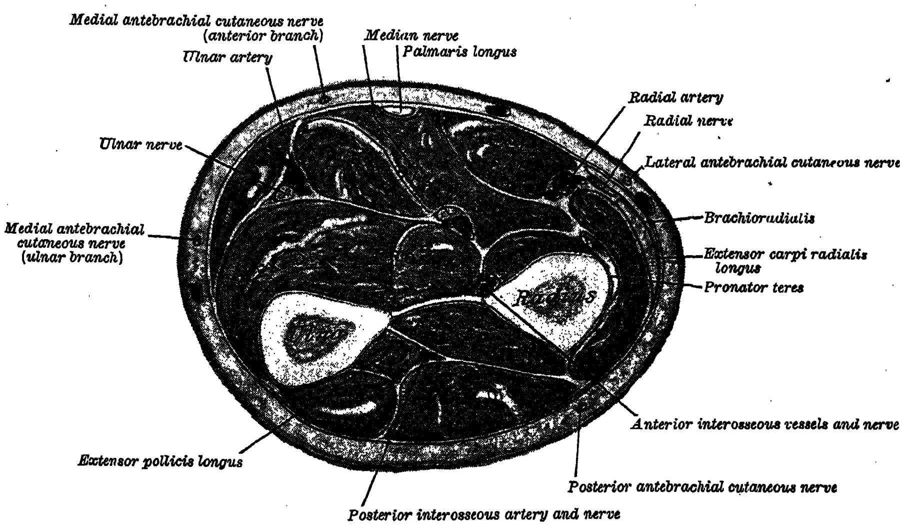
The **deep branch** (fig. 732) passes between the Abductor digiti minimi and Flexor digiti minimi, and through or deep to the origin of the Opponens digiti

FIG. 734.—A transverse section through the left wrist. Superior aspect.



The section is slightly oblique and divides the distal row of the carpus, and the bases of the first, second and third metacarpal bones. The arrangement of the tendons of the flexors of the fingers shown in the figure is not diagrammatic but represents the actual condition at this level. Observe that the carpometacarpal joint of the thumb is shut off from the joint between the trapezium and the base of the second metacarpal bone.

FIG. 735.—A transverse section through the middle of the forearm.

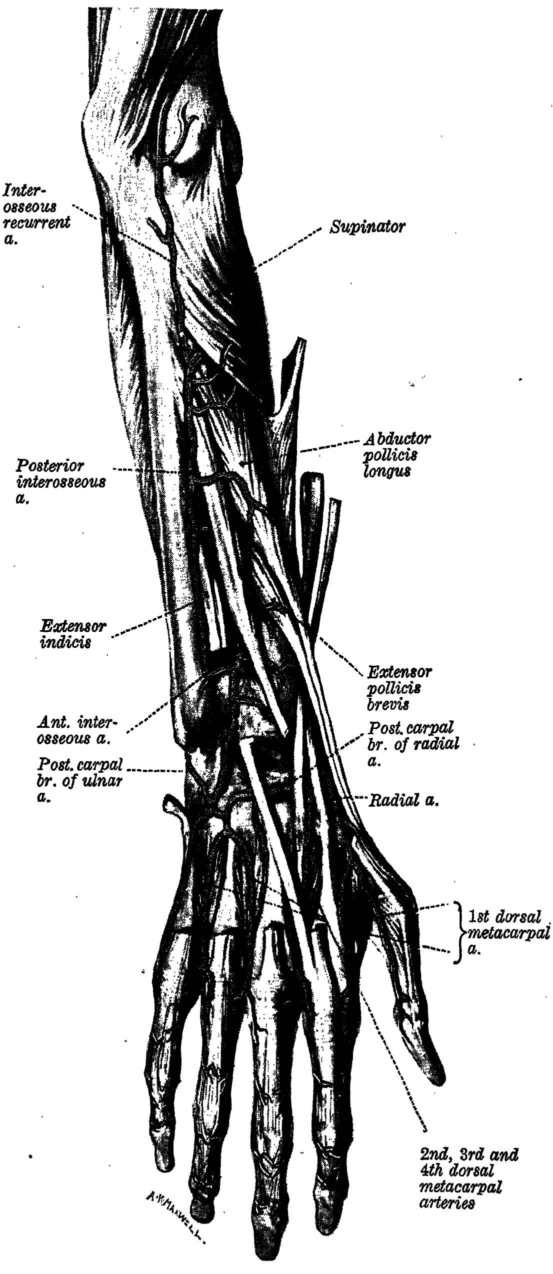


minimi; it anastomoses with the radial artery, and completes the deep palmar arch; it is accompanied by the deep branch of the ulnar nerve.

The **superficial palmar arch** (superficial volar arch) (fig. 730) is formed mainly by the ulnar artery, which enters the hand with the ulnar nerve in

front of the flexor retinaculum (transverse carpal ligament), and on the lateral side of the pisiform bone. It then passes across the palm, forming the superficial palmar arch, the convexity of which is directed towards the fingers, and is placed at the level of a line drawn across the hand from the distal border of the root of the extended thumb. The arch is usually completed by a branch of the arteria radialis indicis, but sometimes by the superficial palmar artery or a branch of the arteria princeps pollicis. The arch is covered by the palmaris brevis and the palmar aponeurosis, and lies on the Flexor digiti minimi, the branches of the median nerve, the flexor tendons and the Lumbricals.

FIG. 736.—The arteries of the posterior surface of the right forearm and hand.



Three **palmar digital arteries** (fig. 730) arise from the convexity of the superficial palmar arch and proceed downwards on the second, third and fourth Lumbricals. Each is joined by the corresponding palmar metacarpal artery from the deep palmar arch, and then divides into a pair of vessels, which run along the contiguous sides of the index, middle, ring and little fingers, behind the corresponding digital nerves; they anastomose freely in the subcutaneous tissue of the finger tips and by smaller branches near the interphalangeal joints. Each gives off two dorsal branches, which anastomose with the dorsal digital arteries, and supply the soft parts on the back of the middle and distal phalanges, including the matrix of the finger-nail. The palmar digital artery for the medial side of the little finger springs from the arch under cover of the Palmaris brevis.

A free anastomosis takes place between the radial and ulnar arteries, (*a*) on the front and back of the wrist through the anterior and posterior carpal arches, and (*b*) in the hand through the superficial and deep palmar arches, and their digital and metacarpal branches.

Applied Anatomy.—Wounds of the palmar arches are always difficult to deal with. When the superficial arch is involved it is generally possible (enlarging the wound when necessary) to secure the vessel and tie it on both sides of the bleeding point; or in cases where it is found impossible to encircle the vessel with a ligature, a pair of artery clips may be applied and left on for twenty-four or forty-eight hours. Failing this, the wound

may be plugged with gauze and an outside dressing carefully bandaged on. The plug should remain untouched for three or four days. It is useless in these cases to ligature one of the arteries of the forearm alone, and simultaneous ligature of both radial and ulnar arteries above the wrist is often unsuccessful, on account of the anastomosis carried on by the carpal networks. Therefore, upon the failure of pressure to arrest hæmorrhage, it is expedient to apply a ligature to the brachial artery.

When an incision for deep-seated suppuration in the synovial sheath of the flexor tendons is required, the situation of the superficial arch must always be borne in mind, and the incisions placed either above or below it. The position of the digital branches of the artery must also be remembered, and the incisions made in front of the heads of the metacarpal bones and not between them.

THE ARTERIES OF THE TRUNK

The Descending Aorta

The **descending aorta** is divided into two portions, *descending thoracic* and *abdominal*, in correspondence with the two great cavities in which it is situated.

The Descending Thoracic Aorta (fig. 737)

The **descending thoracic aorta** is contained in the posterior mediastinum. It begins at the lower border of the fourth thoracic vertebra, where it is continuous with the aortic arch (p. 694), and ends in front of the lower border of the twelfth thoracic vertebra at the aortic opening in the Diaphragm. At its origin it is situated on the left of the vertebral column; as it descends it approaches the median plane, and at its termination lies in front of the column.

Relations.—It is in relation, *anteriorly*, from above downwards, with the root of the left lung, the pericardium—which separates it from the left atrium—the œsophagus and the Diaphragm; *posteriorly*, with the vertebral column and the hemiazygos veins; on the *right side*, with the azygos vein and thoracic duct and, in the lower part of its course, with the right pleura and lung; on the *left side*, with the left pleura and lung. The œsophagus, with its accompanying plexus of nerves, lies on the right side of the aorta above; but at the lower part of the thorax it is placed in front of the vessel, and, close to the Diaphragm, is placed anteriorly and to its left side.

The Branches of the Descending Thoracic Aorta

Visceral	Pericardial.	*Parietal*	Mediastinal.
	Bronchial.		Phrenic.
	Œsophageal.		Posterior intercostal.
			Subcostal.

The **pericardial branches** consist of a few small vessels which are distributed to the posterior surface of the pericardium.

The **bronchial arteries** vary in number, size and origin. There is as a rule one **right bronchial artery**, which arises from the third posterior (first aortic) intercostal artery, or from the upper left bronchial artery. It runs on the posterior surface of the right bronchus, dividing and subdividing along the bronchial tubes, supplying them, the areolar tissue of the lung and the bronchopulmonary lymph glands; it also sends branches to the pericardium and the œsophagus. The **left bronchial arteries**, usually two in number, arise from the descending thoracic aorta, the upper opposite the fifth thoracic vertebra, and the lower just below the left bronchus. They run on the posterior surface of the left bronchus and have a distribution similar to that of the right bronchial artery.

The **œsophageal arteries**, four or five in number, arise from the front of the aorta, and pass obliquely downwards to the œsophagus; on this they form a vascular chain, which anastomoses above with the œsophageal branches of the inferior thyroid arteries, and below with ascending branches from the left phrenic and left gastric arteries.

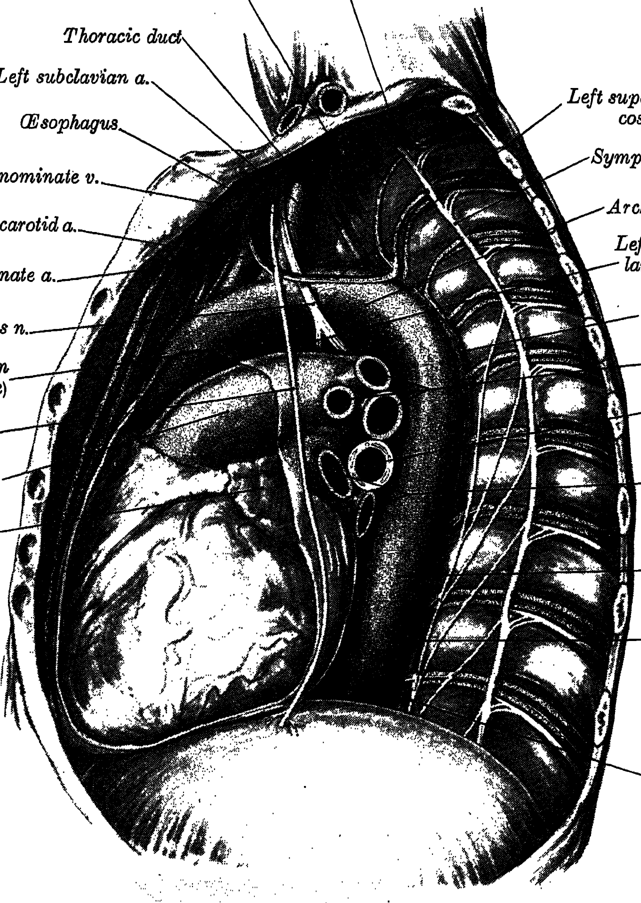
The **mediastinal branches** are numerous small vessels which supply the lymph glands and the areolar tissue in the posterior mediastinum.

The **phrenic branches** are small, and arise from the lower part of the descend-

ing thoracic aorta; they are distributed to the posterior part of the upper surface of the Diaphragm, and anastomose with the musculophrenic and pericardiacophrenic arteries.

The posterior intercostal arteries.—There are usually nine pairs of posterior intercostal arteries derived from the descending thoracic aorta. They arise from the back of the vessel, and are distributed to the lower nine intercostal

FIG. 737.—The heart and the thoracic aorta. Left lateral aspect.



spaces, the first and second spaces being supplied by the superior intercostal artery, a branch of the costocervical trunk of the subclavian artery (p. 739). The *right* posterior intercostal arteries are longer than the left, on account of the position of the aorta on the left side of the vertebral column; they cross the bodies of the vertebræ behind the œsophagus, thoracic duct and vena azygos, and are covered with the right lung and pleura. The *left* posterior intercostal arteries run backwards on the sides of the vertebræ and are covered with the left lung and pleura; the upper two vessels are crossed by the left superior intercostal vein, the lower vessels by the hemiazygos veins. The further course of the posterior intercostal arteries is practically the same on both sides. Opposite the heads of the ribs the sympathetic trunk passes downwards in front of them, and the splanchnic nerves also descend in front of the lower arteries.

Each artery (fig. 737) crosses its intercostal space obliquely towards the

angle of the upper rib, and thence is continued forward in the costal groove. It is placed at first between the pleura and the posterior intercostal membrane, as far as the angle of the rib ; from this onward it runs between the Internal intercostal and the Intercostalis intimus muscle (p. 553), and anastomoses in front with the anterior intercostal branch of the internal mammary or musculophrenic artery. Each artery is accompanied by a vein and a nerve, the former being above and the latter below the artery, except in the upper spaces, where the nerve is at first above the artery. The third posterior (first aortic) intercostal artery anastomoses with the superior intercostal artery, and may form the chief supply of the second intercostal space. The lower two posterior intercostal arteries are continued anteriorly from the intercostal spaces into the abdominal wall and anastomose with the subcostal, superior epigastric and lumbar arteries.

Each posterior intercostal artery gives off the following branches :

Posterior.	Muscular.
Collateral intercostal.	Lateral cutaneous.
Mammary.	

Each **posterior branch** runs backwards through a space which is bounded above and below by the necks of the ribs, medially by the body of a vertebra, and laterally by a superior costotransverse ligament (anterior costotransverse ligament). It gives off a *spinal branch*, which enters the vertebral canal through the intervertebral foramen, and is distributed to the vertebræ and to the spinal cord and its membranes, anastomosing with the spinal arteries above and below and with the artery of the opposite side. The posterior branch then courses over the transverse process with the posterior primary ramus of the thoracic nerve, supplies offshoots to the muscles of the back, and a cutaneous twig which accompanies the cutaneous branch of the posterior primary ramus of the nerve.

The **collateral intercostal branch** comes off the posterior intercostal artery near the angle of the rib, and descends to the upper border of the rib below, along which it courses to anastomose with an intercostal branch of the internal mammary or musculophrenic artery. The collateral branches of the lower two vessels are sometimes absent ; if present, they are small and end in the abdominal muscles.

Muscular branches are given to the Intercostal and Pectoral muscles and to the Serratus anterior ; they anastomose with the superior and lateral thoracic branches of the axillary artery.

The **lateral cutaneous branches** accompany the lateral cutaneous branches of the thoracic nerves.

Mammary branches are given off by the vessels in the second, third and fourth spaces ; they increase considerably in size during the period of lactation.

The **right bronchial artery** may arise from the right third posterior (first aortic) intercostal artery (p. 757).

Applied Anatomy.—The position of the posterior intercostal vessels should be borne in mind in performing the operation of paracentesis thoracis. The puncture should never be made nearer the posterior median line than the angle of the rib, as the artery crosses the space medial to this point. In the lateral portion of the chest, where the puncture is usually made, the artery lies at the upper part of the intercostal space, and therefore the puncture should be made just above the upper border of the rib forming the lower boundary of the space.

The relation of the Diaphragm to the deep surface of the lower intercostal spaces must be remembered, otherwise the abdominal cavity may be opened inadvertently while making incisions in these spaces.

The **subcostal arteries**, the last pair of arteries arising from the descending thoracic aorta, are in series with the posterior intercostal arteries, but are named *subcostal* because they are situated below the twelfth rib. Each artery runs laterally over the body of the twelfth thoracic vertebra, and behind the splanchnic nerves, the gangliated trunk of the sympathetic, the pleura and the Diaphragm. The right artery also passes behind the thoracic duct and the vena azygos, and the left behind the inferior hemiazygos vein. Each artery then enters the abdomen under cover of the lateral arcuate ligament (lateral lumbocostal arch), and courses with the twelfth thoracic nerve along the lower

border of the twelfth rib, anterior to the Quadratus lumborum and posterior to the kidney. The right artery runs behind the ascending, and the left behind the descending, colon. Each artery then pierces the aponeurosis of origin of the Transversus abdominis, and, passing forward between this muscle and the Obliquus internus, anastomoses with the superior epigastric, lower posterior intercostal and lumbar arteries. Each subcostal artery gives off a posterior branch, which is distributed like the posterior branch of a posterior intercostal artery.

A small **aberrant artery** is sometimes found arising from the right side of the descending thoracic aorta near the origin of the right bronchial. It passes upwards and to the right behind the trachea and the œsophagus, and may anastomose with the right superior intercostal artery. It represents the remains of the right dorsal aorta (p. 149), and in a small proportion of cases is enlarged to form the first part of the right subclavian artery.

Peculiarities.—The lumen of the aorta is occasionally found to be partly or completely obliterated, either at the aortic isthmus, or close to the point where the ductus arteriosus opens into it. This condition is known as *coarctation of the aorta.* It may be either congenital or acquired. In the former case the infant usually dies at or soon after birth. When acquired, it is apparently due to an abnormal extension of the peculiar tissue of the ductus into the aortic wall, giving rise to a simultaneous stenosis of both vessels as it contracts after birth. This form of coarctation is compatible with many years of normal life, and leads to the establishment of an extensive collateral circulation to carry blood to the aorta immediately below the stenosis. In one case the following vessels were involved—Firstly, the internal mammary anastomosed with the posterior intercostal arteries and with the phrenic of the abdominal aorta by means of the musculophrenic and pericardiacophrenic, and its superior epigastric branch anastomosed freely with the inferior epigastric. Secondly, the costocervical trunk anastomosed anteriorly by means of a large branch with the third posterior (first aortic) intercostal, and posteriorly with the posterior branch of the same artery. Thirdly, the inferior thyroid, by means of a branch about the size of an ordinary radial, formed a communication with the third posterior intercostal. Fourthly, the transverse cervical, by means of very large communications, anastomosed with the posterior branches of the posterior intercostals. Fifthly, the branches (of the subclavian and axillary) going to the side of the chest anastomosed freely with the lateral branches of the intercostals. In a second case Wood described the anastomoses in a somewhat similar manner, adding the remark, that "the blood which was brought into the aorta through the anastomoses of the intercostal arteries appeared to be expended principally in supplying the abdomen and pelvis; while the supply to the lower extremities had passed through the internal mammary and epigastrics."

Applied Anatomy.—Aneurysm of the descending thoracic aorta most commonly extends backwards along the left side of the vertebral column and leads to absorption of the bodies of the vertebræ (but not of the intervertebral discs) and of the ribs; pressure on the intercostal nerves may give rise to radiating pains in the left upper intercostal spaces; after erosion of the vertebræ the aneurysm may compress the spinal nerve-roots or ultimately the spinal cord, producing pains in the chest, back or loins, or paralysis below the site of the lesion; at the same time the aneurysm may project backwards under the skin as a pulsating swelling. If the aneurysm extend forward, it may press upon and displace the heart, giving rise to palpitation and other symptoms of disease of that organ; it may displace or compress the œsophagus, causing pain and difficulty of swallowing, and ultimately even open into it by ulceration, producing fatal hæmorrhage. If the aneurysm extend to the right side, it may press upon the thoracic duct; it may burst into the pleural cavity, or into the lung; or it may open into the posterior mediastinum. Pressure on one of the bronchi, usually the left, will cause cough, and in time set up bronchiectasis. Of late years, the diagnosis of thoracic aneurysm has been much facilitated by the employment of the x-rays, by means of which the outline of the sac may be demonstrated.

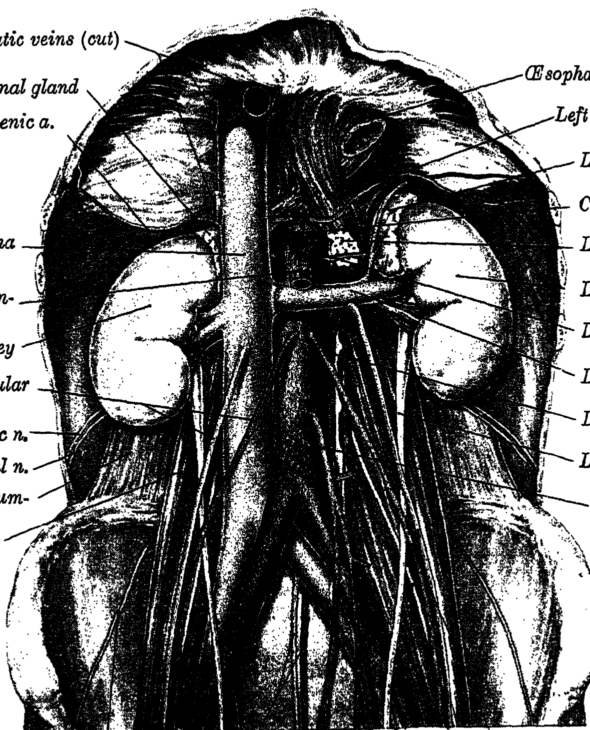
The Abdominal Aorta (fig. 738)

The **abdominal aorta** begins at the aortic opening of the Diaphragm, in front of the lower border of the body of the last thoracic vertebra, and, descending in front of the vertebral column, ends on the body of the fourth lumbar vertebra, a little to the left of the median plane, by dividing into the two common iliac arteries. It diminishes rapidly in size, in consequence of the large branches which arise from it.

Relations.—*Anteriorly* the abdominal aorta is at first related to the cœliac artery and its branches, the cœliac plexus of nerves and the lesser sac of

peritoneum (omental bursa), which intervene between it and the papillary process of the liver and the lesser omentum. Immediately below this level the aorta gives origin to the superior mesenteric artery, and is crossed by the left renal vein. The body of the pancreas, with the splenic vein closely applied to its posterior aspect, extends obliquely upwards and to the left across the abdominal aorta, but is separated from it by the vessels already mentioned. Below the pancreas the aorta is related to the proximal parts of its testicular (or ovarian) branches, and is crossed by the third part of the duodenum. In its lowest part the aorta comes into intimate relationship with the posterior parietal peritoneum and is crossed by the root of the mesentery and its contents. The

Fig. 738.—The abdominal aorta and its branches.



large nerves of the aortic plexus, the inferior mesenteric ganglion, and the commencement of the inferior mesenteric artery all intervene between the vessel and the peritoneum.

Posteriorly the abdominal aorta lies on the upper four lumbar vertebræ, the corresponding intervertebral discs and the anterior longitudinal ligament. The lumbar arteries; which arise from its dorsal aspect, and the third and fourth and sometimes the second left lumbar veins, which cross behind it to reach the inferior vena cava, intervene between the vessel and the ligament. The vessel may overlap the anterior border of the left Psoas major muscle to a slight extent.

On the *right side*, it is related above to the cisterna chyli and the thoracic duct, the azygos vein, and the right crus of the Diaphragm, which overlaps it and separates it from the inferior vena cava and the right cœliac ganglion. Below the level of the second lumbar vertebra it is in contact with the inferior vena cava.

On the *left side*, it is related to the left crus of the Diaphragm and the left cœliac ganglion, above. Opposite the second lumbar vertebra it comes into

relation with the duodeno-jejunal flexure and the sympathetic trunk, which continues downwards along the left side of the vessel. The fourth (ascending) part of the duodenum and the inferior mesenteric vessels constitute additional relations.

Applied Anatomy.—Aneurysm of the abdominal aorta occurs most frequently at its upper part, close to and often involving the cœliac artery, because in this situation the vessel rapidly narrows after giving off several large branches, and its walls have lost the support afforded higher up by the crura of the Diaphragm.

If the aneurysm enlarges forwards it forms a pulsating tumour in the left hypochondriac or epigastric regions; by pressure upwards at the same time it may interfere with the movements of the Diaphragm and embarrass respiration, or may compress the œsophagus and produce dysphagia; pressure on the stomach and cœliac plexus gives rise to dyspepsia, while jaundice may follow pressure on the bile duct and duodenum, or polyuria, albuminuria, hæmaturia and anuria pressure on the renal vessels and nerves; if the inferior vena cava is compressed there may be œdema of the lower limbs. This form of aneurysm may burst into the peritoneal cavity, behind the peritoneum, between the layers of the mesentery, or more rarely into the duodenum.

When an aneurysm of the abdominal aorta enlarges backwards it usually produces absorption of the bodies of the vertebræ. Pain is invariably present and is usually of two kinds—a fixed and constant pain in the back, caused by the tumour eroding the bones, and a sharp lancinating pain radiating to the loins, hypogastrium and buttocks along the branches of the lumbar nerves which are pressed on by the tumour.

The abdominal aorta has been tied in several cases, and although none of the patients permanently recovered, still, as one case lived forty-eight days, the possibility of the re-establishment of the circulation may be considered to be proved.

Collateral Circulation.—The collateral circulation would be carried on by the anastomoses between the internal mammary and the inferior epigastric arteries; by the free communication between the superior and inferior mesenteric arteries, if the ligature were placed between these vessels; or by the anastomosis between the inferior mesenteric and the internal pudendal arteries, when (as is more common) the point of ligature is below the origin of the inferior mesenteric artery; and possibly by the anastomoses of the lumbar arteries with the branches of the internal iliac (hypogastric) artery.

The Branches of the Abdominal Aorta (fig. 738)

The branches of the abdominal aorta may be divided into four sets: ventral, lateral, dorsal and terminal. The ventral and lateral branches are distributed to viscera, while the dorsal branches supply the body wall.

Ventral branches.
Cœliac.
Superior mesenteric.
Inferior mesenteric.

Lateral branches.
Phrenic.
Middle suprarenal.
Renal.
Testicular (in the male).
Ovarian (in the female).

Dorsal branches.
Lumbar.
Median sacral.

Terminal branches.
Common iliac.

The ventral branches, which supply the alimentary canal and its derivatives, represent fused ventral branches of the two dorsal aortæ and are therefore unpaired. The lateral branches, which supply the derivatives from the mesonephric ridges, are all paired vessels. Of the dorsal branches, the lumbar arteries, which represent persistent intersegmental arteries (p. 150), are paired, but the median sacral is an unpaired vessel. The terminal branches are paired.

The Cœliac Artery (figs. 739, 740)

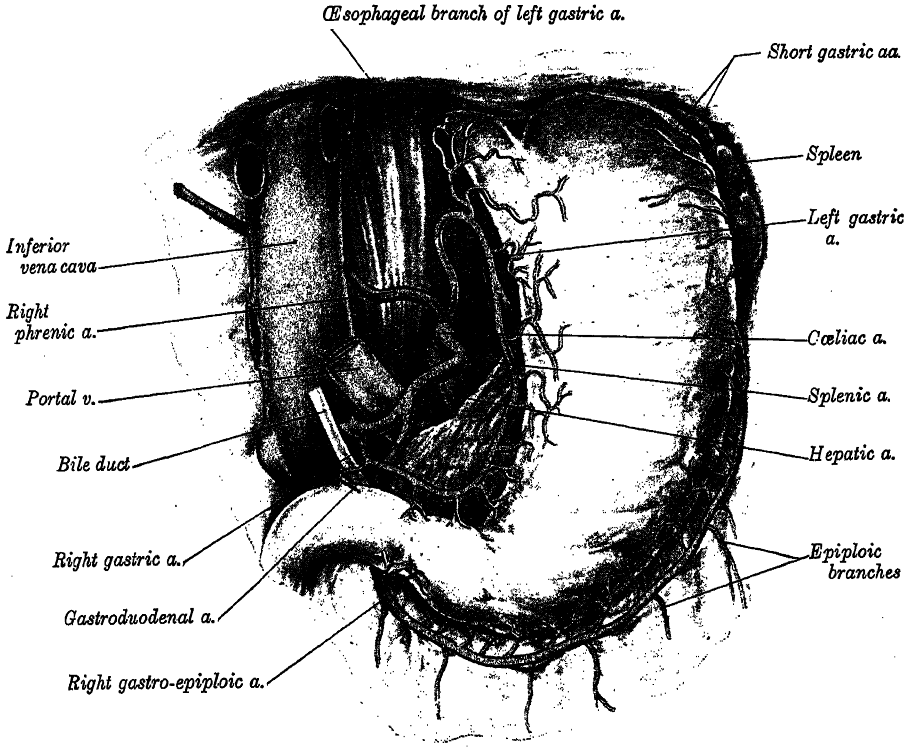
The cœliac artery is a thick trunk, about 1·25 cm. long, which arises from the front of the aorta, just below the aortic opening of the Diaphragm; it passes nearly horizontally forwards above the pancreas and the splenic vein,

and divides into three branches, (1) *left gastric*, (2) *hepatic*, and (3) *splenic*; it occasionally gives off one of the phrenic arteries.

Relations.—The cœliac artery lies behind the lesser sac of the peritoneum (omental bursa), and is surrounded by the cœliac plexus of nerves, which sends branches along the three divisions of the artery. On its *right side* it is related to the right cœliac ganglion, the right crus of the Diaphragm, and the caudate process of the liver: on its *left side* to the left cœliac ganglion, the left crus of the Diaphragm, and the cardiac end of the stomach. *Below* it is related to the upper border of the pancreas and the splenic vein.

1. The **left gastric artery** (fig. 739), which is the smallest branch of the cœliac artery, passes upwards and to the left, behind the lesser sac, to the cardiac

FIG. 739.—The cœliac artery and its branches.



The liver and the lesser omentum have been removed. The posterior wall of the lesser sac and the anterior layer of the greater omentum have been taken away.

end of the stomach. In its course, the left gastric artery lies close to the left phrenic artery and medial to or in front of the left suprarenal gland. At or near the cardiac end of the stomach it gives off two or three *œsophageal branches*, which ascend through the œsophageal opening of the Diaphragm and anastomose with the aortic œsophageal arteries; others supply the cardiac part of the stomach and anastomose with branches of the splenic artery. The artery then turns forwards and downwards in the left gastropancreatic fold, and runs (frequently as two branches) along the lesser curvature of the stomach to the pylorus, between the layers of the lesser omentum; it gives branches to both surfaces of the stomach and anastomoses with the right gastric artery.

2. The **hepatic artery** (figs. 739, 741) is intermediate in size between the left gastric and splenic arteries. It is accompanied by the hepatic plexus of nerves, and is first directed forwards and to the right, to the upper margin of the first part of the duodenum, passing below the medial end of the opening into the lesser sac (epiploic foramen) (fig. 1162). It then crosses in front of the portal vein, and ascends between the layers of the lesser omentum and in

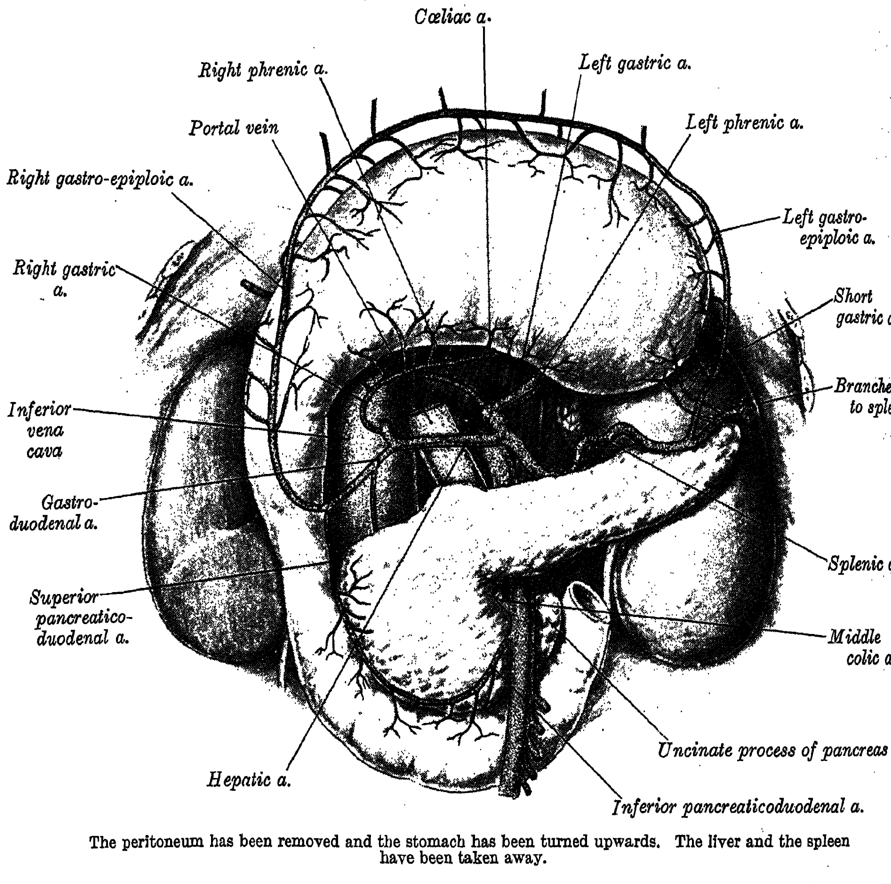
front of the opening into the lesser sac, to the porta hepatis, where it divides into right and left branches which supply the corresponding lobes of the liver, accompanying the ramifications of the portal vein and hepatic ducts. In the lesser omentum the hepatic artery lies in front of the portal vein, and on the left of the bile-duct and its right branch crosses behind the common hepatic duct (fig. 741). The distribution of the hepatic artery within the liver is described with the anatomy of the liver, in the section on Splanchnology.

Its branches are :

Right gastric. Gastroduodenal. Cystic.

The **right gastric artery** (fig. 739) arises from the hepatic artery above the first part of the duodenum ; it descends in the lesser omentum to the pyloric

FIG. 740.—The cœliac artery and its branches.



The peritoneum has been removed and the stomach has been turned upwards. The liver and the spleen have been taken away.

end of the stomach, and passes from right to left along its lesser curvature, supplying it with branches, and anastomosing with the left gastric artery.

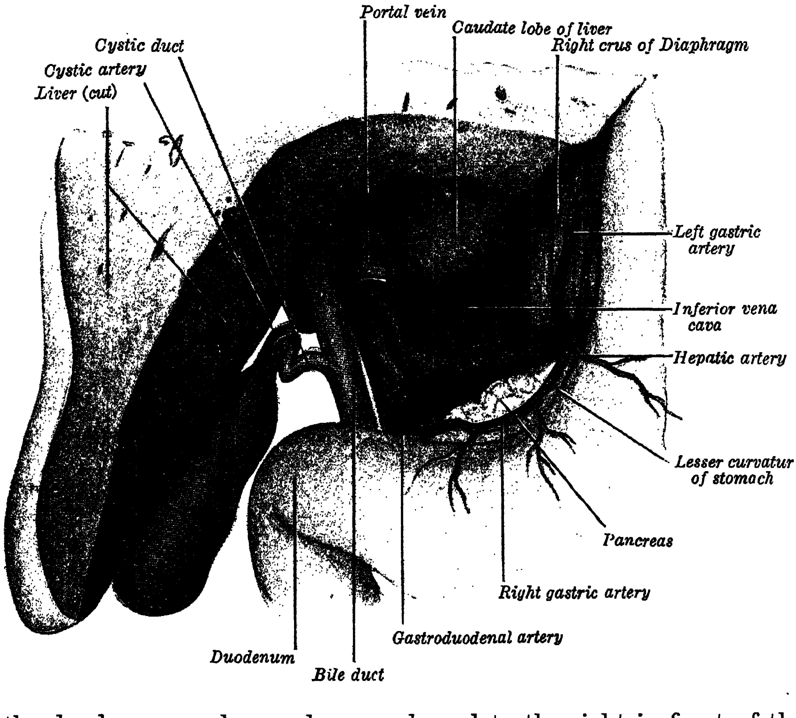
The **gastroduodenal artery** (figs. 739, 740) is a short but large branch, which descends between the first part of the duodenum and the neck of the pancreas, lying immediately to the right of the line along which the peritoneum is reflected from the posterior surface of the first half-inch of the duodenum (fig. 1161). At the lower border of the duodenum it divides into the *right gastro-epiploic* and the *superior pancreaticoduodenal* arteries. Previous to its division it gives off two or three small branches to the pyloric end of the stomach and to the pancreas.

The **right gastro-epiploic artery** (figs. 739, 740), which is the larger terminal branch of the gastroduodenal artery, skirts the right margin of the lesser sac and then runs from right to left along the greater curvature of the stomach, between the layers of the greater omentum. It ends by anastomosing with

the left gastro-epiploic branch of the splenic artery. Except at the pylorus, where it is in contact with the stomach, it lies about a finger's breadth from the greater curvature. This vessel gives off numerous branches, some of which ascend to supply both surfaces of the stomach, while others descend to supply the greater omentum.

The **superior pancreaticoduodenal artery** (fig. 740) is usually represented by an anterior and a posterior vessel. The *anterior* descends on the front of the groove between the duodenum and the head of the pancreas. It supplies both of these organs, and anastomoses with the anterior division of the inferior pancreaticoduodenal branch of the superior mesenteric artery, and with the pancreatic branches of the splenic artery. The *posterior superior pancreatico-duodenal artery* arises from the gastroduodenal at the upper border of the first

FIG. 741.—Drawing of a dissection to show the relations of the hepatic artery, bile duct and portal vein in the lesser omentum.



part of the duodenum, and runs downwards and to the right in front of the portal vein and the bile duct. It then passes downwards on the back of the head of the pancreas, supplying branches to the gland and to the duodenum, and crosses behind the bile duct, just before that structure pierces the duodenal wall. It ends by anastomosing with the posterior division of the inferior pancreaticoduodenal artery.

The **cystic artery** (fig. 741), usually arises from the right branch of the hepatic artery, and passes behind the common hepatic and cystic ducts to gain the upper surface of the neck of the gall-bladder, on which it runs downwards and forwards before dividing into *superficial* and *deep* branches. The former ramifies on the free, and the latter on the attached, surface of the gall-bladder. Occasionally the cystic artery arises from the trunk of the hepatic artery or, rarely, from the gastroduodenal artery, and crosses in front of the bile duct to reach its destination.

3. The **splenic artery** (figs. 739, 740), which is the largest branch of the cœliac artery, is remarkable for the tortuosity of its course. Surrounded by the splenic plexus of nerves, and accompanied by the splenic vein, which lies behind the pancreas, it passes horizontally to the left, behind the stomach and the lesser sac of the peritoneum (omental bursa), and along the upper border of the pancreas; it crosses in front of the left suprarenal gland and the upper

part of the left kidney, and enters the lienorenal ligament. On arriving near the spleen it gives origin to five or six branches which enter the hilum of the spleen.

Its branches are :

Pancreatic.	Left gastro-epiploic.
Short gastric.	Splenic.

The **pancreatic branches** (fig. 740) are numerous small vessels supplying the body and tail of the pancreas ; they are derived from the splenic artery as it runs along the upper border of the pancreas. One branch, larger than the rest, is sometimes given off near the tail of the pancreas ; it runs from left to right near the posterior surface of the gland, following the course of the pancreatic duct, and is sometimes called the *arteria pancreatica magna*. These vessels anastomose with the pancreatic branches of the superior and inferior pancreaticoduodenal arteries.

The **short gastric arteries** (fig. 740) consist of from five to seven small branches which arise from the end of the splenic artery, and from its terminal divisions. They pass between the layers of the gastrosplenic ligament, and are distributed to the fundus of the stomach, anastomosing with branches of the left gastric and left gastro-epiploic arteries.

The **left gastro-epiploic artery** (figs. 739, 740), the largest branch of the splenic artery, runs from left to right about a finger's breadth from the greater curvature of the stomach, between the layers of the greater omentum, and anastomoses with the right gastro-epiploic artery. It distributes several ascending branches to both surfaces of the stomach ; others descend to supply the greater omentum. It should be observed that the splenic artery and its gastric branches pass round the left border of the lesser sac of the peritoneum (omental bursa) (fig. 1162).

The **splenic branches** enter the hilum of the spleen between the two layers of the lienorenal ligament. Their distribution within the spleen is described with the anatomy of that organ (p. 1424).

Peculiarities.—Although the arrangement of the cœliac artery and its branches is fairly constant, three variations are worthy of mention. (1) An *accessory right hepatic artery* sometimes arises from the superior mesenteric artery and runs upwards and to the right, passing behind the portal vein to gain the right extremity of the porta hepatis. (2) An *accessory left hepatic artery* not infrequently arises from the left gastric artery and courses to the right between the two layers of the lesser omentum. It enters the lower part of the fissure for the ligamentum venosum to gain the left extremity of the porta hepatis. (3) An *accessory left gastric artery* may arise from the left branch of the hepatic artery and traverse the lesser omentum to gain the lesser curvature of the stomach.

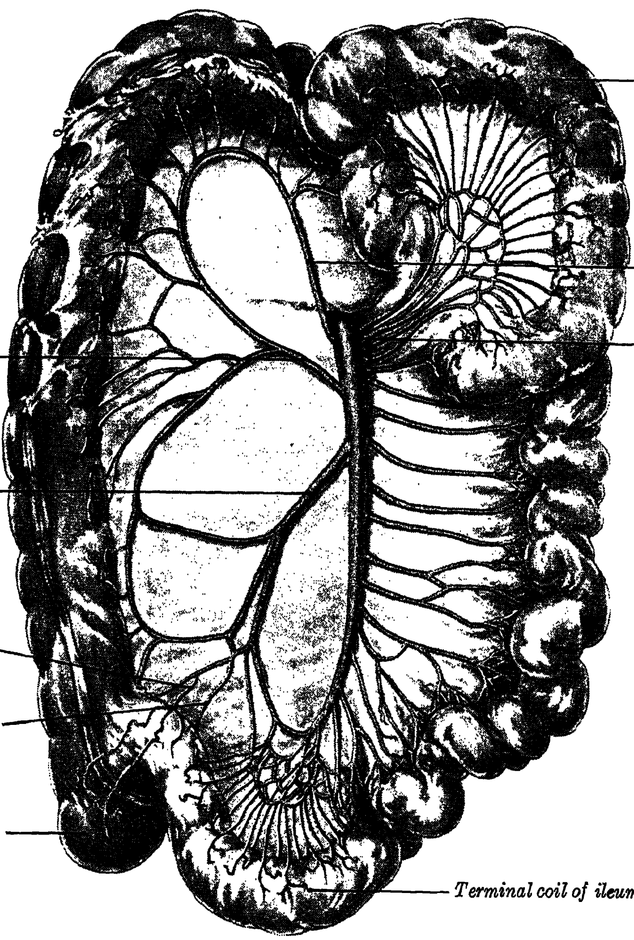
The Superior Mesenteric Artery (fig. 742)

The **superior mesenteric artery** supplies the whole of the small intestine except the first part of the duodenum ; it also supplies the cæcum and the ascending colon and most of the transverse colon. It arises from the front of the aorta about 1 cm. below the cœliac artery, and is crossed at its origin by the splenic vein and the body of the pancreas. Near its origin it is separated from the front of the aorta by the left renal vein. Thereafter it passes downwards and forwards, anterior to the uncinate process of the head of the pancreas and the third part of the duodenum, and descends between the layers of the mesentery and near its root until it reaches the right iliac fossa, where, considerably diminished in size, it anastomoses with one of its own branches, viz. the ileocolic artery. In its course it crosses in front of the inferior vena cava, the right ureter, and Psoas major, and forms an arch, the convexity of which is directed forwards, downwards, and to the left side. It is accompanied by the superior mesenteric vein, which lies to its right side, and is surrounded by the superior mesenteric plexus of nerves. Its branches are :

Inferior pancreaticoduodenal.	Ileocolic.
Jejunal and ileal.	Right colic.
Middle colic.	

The **inferior pancreaticoduodenal artery** (fig. 740) springs from the superior mesenteric artery or from its first jejunal branch, opposite the upper border of the third part of the duodenum. Usually it divides at once into an anterior and a posterior branch. The *anterior branch* courses to the right in front of the head of the pancreas and then ascends to anastomose with the anterior superior pancreaticoduodenal artery. The *posterior branch* passes upwards and to the right behind the head of the pancreas, which it sometimes pierces, to anastomose with the posterior superior pancreaticoduodenal artery. Both branches supply

FIG. 742.—The superior mesenteric artery and its branches.

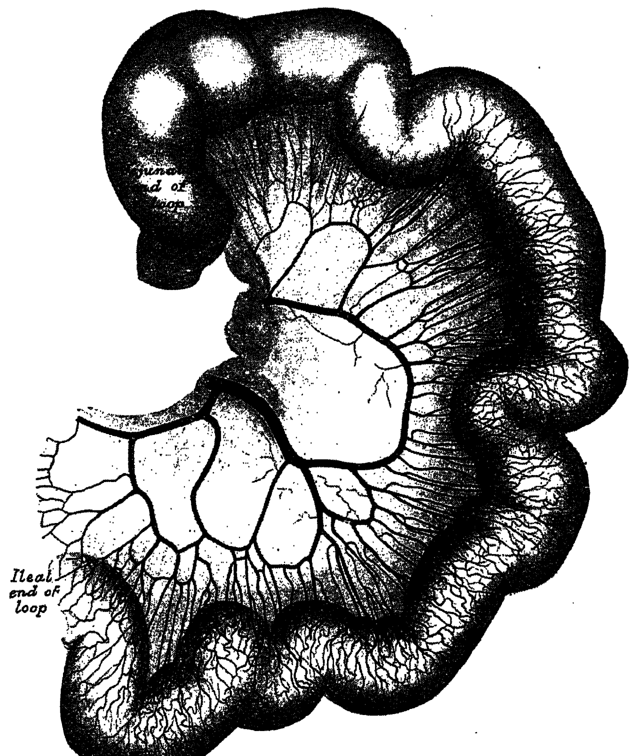


The first coil of the jejunum and the terminal coil of the ileum have been spread out to show the arrangement of their arteries.

the head of the pancreas, including its uncinate process, and the second, third and fourth parts of the duodenum.

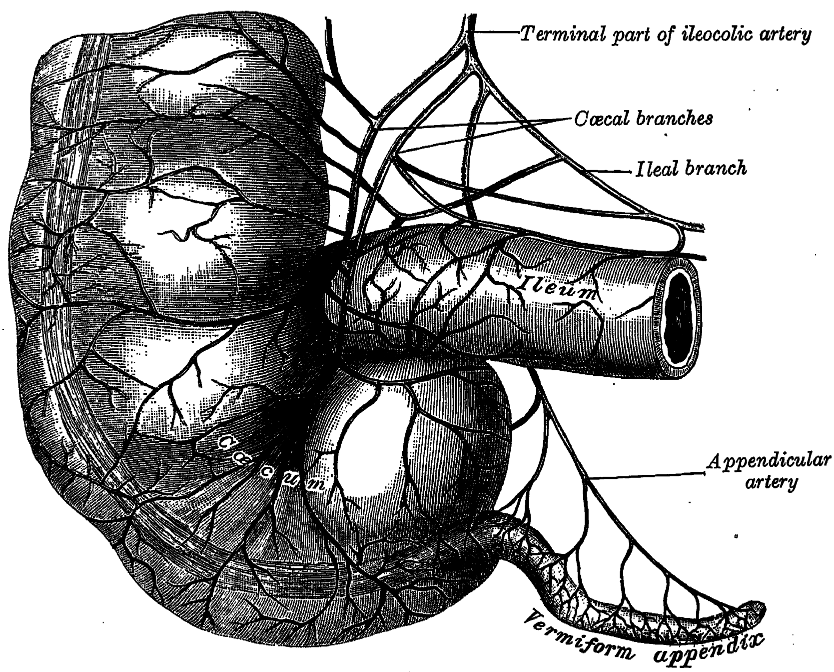
The **jejunal and ileal branches** (fig. 742) arise from the left side of the superior mesenteric artery. They are usually from twelve to fifteen in number, and are distributed to the jejunum and ileum, with the exception of the terminal part of the latter, which is supplied by the ileocolic artery. They run nearly parallel with one another between the layers of the mesentery, each vessel dividing into two branches, which unite with adjacent branches, to form a series of arches (fig. 743). The branches which arise from the arches unite to form a second series of arches, and the process may be repeated three or four times. In the short, upper part of the mesentery only one set of arches exists, but as the mesentery increases in depth, second, third, fourth, and even fifth groups are present. From the terminal arches numerous small straight vessels arise which

FIG. 743.—A loop of the small intestine showing the distribution of the intestinal arteries. (From a preparation by Hamilton Drummond.)



The vessels were injected while the gut was *in situ*; the gut was then removed, and an x-ray photograph taken.

FIG. 744.—The arteries of the cæcum and vermiform appendix.



supply the intestine. These terminal branches are distributed, roughly alternately, to the right and left surfaces of the gut, and neighbouring vessels do not anastomose with one another.* As a rule the jejunal arteries are longer and less numerous than the ileal arteries. From both groups small branches are given off to the lymph glands and other structures between the layers of the mesentery.

The **ileocolic artery** (fig. 742) is the lowest of the branches arising from the concavity of the superior mesenteric artery. It passes downwards and to the right behind the peritoneum, towards the right iliac fossa, where it divides into a superior and an inferior branch ; the superior branch anastomoses with the right colic artery, the inferior with the end of the superior mesenteric artery. In its course, the ileocolic artery crosses in front of the right ureter, testicular (or ovarian) vessels and Psoas major muscle.

The inferior branch of the ileocolic runs towards the upper border of the ileocolic junction and supplies the following branches (fig. 744) : (*a*) *colic*, which passes upwards on the ascending colon ; (*b*) *anterior* and *posterior cæcal*, which are distributed to the front and back of the cæcum ; (*c*) an *appendicular artery*, which descends behind the termination of the ileum and enters the mesentery of the vermiform appendix ; it runs near the free margin of this mesentery and ends in branches which supply the vermiform appendix ; and (*d*) *ileal*, which runs upwards and to the left on the lower part of the ileum, and anastomoses with the termination of the superior mesenteric artery.

The **right colic artery** (fig. 742) arises from near the middle of the concavity of the superior mesenteric artery, or from a stem common to it and the ileocolic artery. It passes to the right behind the peritoneum, and in front of the right testicular (or ovarian) artery and vein, the right ureter, and the Psoas major, towards the ascending colon. Sometimes the vessel lies at a higher level, and crosses the second part of the duodenum and the lower end of the right kidney. At the colon it divides into a descending branch, which anastomoses with the ileocolic artery, and an ascending branch, which anastomoses with the middle colic artery. These branches form arches, from the convexity of which vessels are distributed to the ascending colon.

The **middle colic artery** (fig. 742) arises from the superior mesenteric artery just below the pancreas and, passing downwards and forwards between the layers of the transverse mesocolon, divides into a right and a left branch ; the former anastomoses with the right colic artery ; the latter with the superior left colic artery, a branch of the inferior mesenteric artery. The arches thus formed are placed about two fingers' breadth from the transverse colon, to which they distribute branches.

The Inferior Mesenteric Artery (fig. 745)

The **inferior mesenteric artery** supplies the terminal part of the transverse colon, the whole of the descending colon, the pelvic colon and the greater part of the rectum. It is smaller than the superior mesenteric artery, and arises from the aorta, about 3 or 4 cm. above its division into the common iliac arteries, and close to the lower border of the third part of the duodenum. It descends behind the peritoneum, lying at first in front of the aorta, and then on its left side. It crosses the left common iliac artery on the medial side of the left ureter, and is continued between the two layers of the pelvic mesocolon into the true pelvis as the *superior rectal* (*superior hæmorrhoidal*) *artery*, and ends on the upper part of the rectum. In the lower part of its course, the inferior mesenteric vein lies on its lateral side. Its branches are :

Superior left colic. Inferior left colic. Superior rectal.

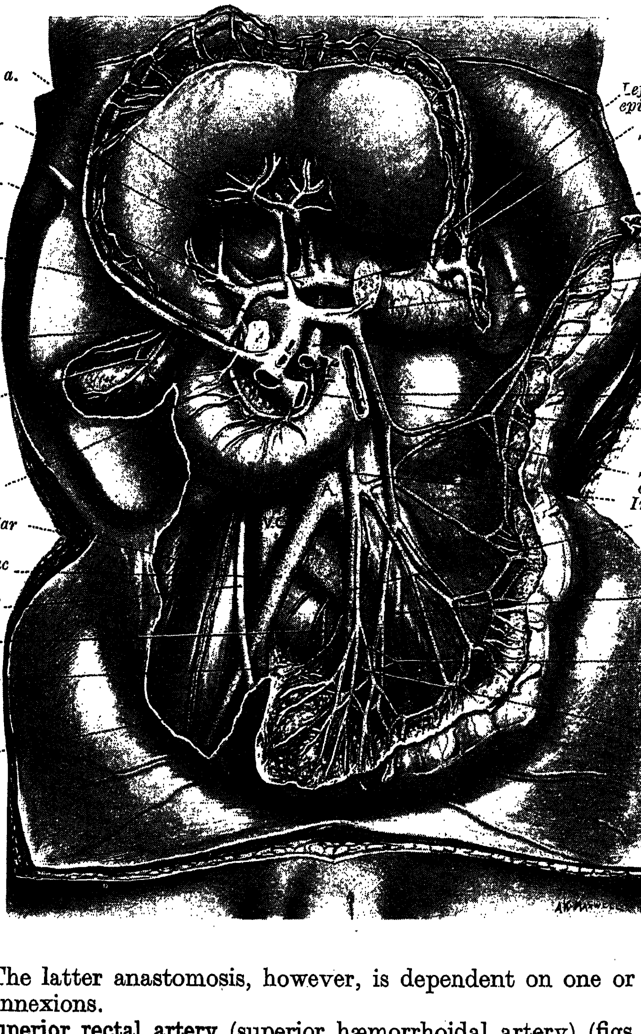
The **superior left colic artery** (fig. 745) runs upwards and to the left behind the peritoneum and in front of the Psoas major, and, after a short but variable course, divides into an ascending and a descending branch ; the trunk or the branches of the artery cross the left ureter and left testicular vessels. The ascending branch passes in front of the left kidney and then between the two layers of the transverse mesocolon, where it anastomoses with the middle colic

* A. J. Cokkinis, *Journal of Anatomy*, vol. lxiv. 1930.

artery ; the descending branch anastomoses with the highest inferior left colic (sigmoid) artery. From the arches formed by these anastomoses branches are distributed to the left half of the transverse colon, and to the descending colon.

The **inferior left colic arteries** (sigmoid arteries) (figs. 745, 746), two or three in number, run obliquely downwards and to the left behind the peritoneum and in front of the left Psoas major, ureter, and testicular vessels. Their branches supply the lower part of the descending colon and the pelvic colon, anastomosing above with the superior left colic artery, and below with the superior rectal

FIG. 745.—The inferior mesenteric vessels and their branches.



artery. The latter anastomosis, however, is dependent on one or more very slender connexions.

The **superior rectal artery** (superior hæmorrhoidal artery) (figs. 745, 746), which is the continuation of the inferior mesenteric artery, descends into the pelvis between the layers of the pelvic mesocolon, crossing, in its course, the left common iliac vessels. It divides, opposite the third sacral vertebra, into two branches ; these descend one on each side of the rectum, and supply its mucous membrane as far as the anal canal, and the upper part of its muscular coat ; about halfway down the rectum the two arteries break up into several small branches. These pierce the muscular coat of the bowel and run straight downwards in the wall of the gut between its muscular and mucous coats, to the level of the Sphincter ani internus ; here by anastomoses with one another they form a system of loops around the lower end of the rectum, and communicate with the middle rectal branches of the hypogastric (internal iliac) artery, and with the inferior rectal branches of the internal pudendal artery.

Applied Anatomy.—As a result of the free anastomoses between the left colic arteries a continuous 'marginal artery' descends near the gut from the left colic flexure to the distal end of the pelvic colon, where it stops, because the superior rectal artery does not divide into arch-forming branches. The point where the lowest left colic artery anastomoses with the superior rectal artery is therefore sometimes named the 'critical point.' Ligature of these two arteries will almost certainly result in gangrene of the part of the rectum which is supplied by them. If, however, the inferior mesenteric artery be tied proximal to the origin of its lowest colic branch, blood can pass through the latter branch into the superior rectal artery.

The Middle Suprarenal Arteries

The **middle suprarenal arteries** are two small vessels which arise, one from each side of the aorta, opposite the superior mesenteric artery. Each artery passes laterally and slightly upwards, over the crus of the Diaphragm, to the suprarenal gland, where it anastomoses with suprarenal branches of the phrenic and renal arteries. On the right side the artery passes behind the inferior vena cava and is closely related to the cœliac ganglion. On the left side it comes into relation with the cœliac ganglion, the splenic artery and the upper border of the pancreas. The distribution of the suprarenal arteries is described on p. 1418.

The Renal Arteries (fig. 738)

The **renal arteries** are two large trunks which arise from the sides of the aorta immediately below the superior mesenteric artery. Each is directed across the corresponding crus of the Diaphragm, nearly at right angles to the aorta. The *right* is longer than the left, on account of the position of the aorta; it passes behind the inferior vena cava, the right renal vein, the head of the pancreas, and the second part of the duodenum. The *left* is a little higher than the right; it lies behind the left renal vein, the body of the pancreas and the splenic vein, and may be crossed by the inferior mesenteric vein. Just before reaching the hilum of the kidney, each artery divides into four or five branches; most of these lie between the renal vein and the pelvis of the ureter, the vein being in front, and the pelvis behind, but one or more branches are usually situated behind the pelvis. Each vessel gives off some small *inferior suprarenal branches* (p. 150) to the suprarenal gland, and supplies twigs to the ureter and the surrounding cellular tissue and muscles.

One or two accessory renal arteries are frequently found, more especially on the left side: they usually arise from the aorta, and may come off above or below the main artery, the former being slightly the more common position. Instead of entering the kidney at the hilum, they usually pierce the upper or lower part of the kidney; an accessory artery to the lower part of the kidney crosses in front of the ureter and, on the right side, usually in front of the inferior vena cava.

The Testicular Arteries (fig. 738)

The **testicular arteries** are two long, slender vessels, which arise from the front of the aorta a little below the renal arteries and are distributed to the testes. Each passes obliquely downwards and laterally behind the peritoneum, resting on the Psoas major; the right artery lies in front of the inferior vena cava and behind the third portion of the duodenum, the right colic and ileocolic arteries, and the terminal part of the ileum; the left artery passes behind the left colic artery, and the lower part of the descending colon. Each artery passes in front of the genitofemoral nerve, the ureter and the lower part of the external iliac artery on its way to reach the deep inguinal ring (abdominal inguinal ring), where it enters the spermatic cord. Accompanied by the other constituents of the spermatic cord, it traverses the inguinal canal and enters the scrotum. At the upper end of the testis it divides into several branches; two or three of these accompany the vas deferens (ductus deferens) and supply the epididymis, anastomosing with the artery of the vas deferens; others pierce

the posterior part of the tunica albuginea, and supply the substance of the testis. In the abdomen the testicular artery supplies small branches to the fat around the kidney, the ureter and the iliac lymph glands ; in the inguinal canal it gives one or two twigs to the Cremaster.

Not infrequently the right testicular artery passes behind the inferior vena cava. It should be remembered that the testicular arteries represent persistent lateral splanchnic branches of the aorta (p. 150) and that as these vessels enter the mesonephros they cross ventral to the supracardinal vein but dorsal to the subcardinal vein. Under normal conditions of development the lateral splanchnic artery which persists as the right testicular artery passes below (caudal to) the particular supra-subcardinal anastomosis which persists to take part in the formation of the inferior vena cava. When it passes above (cranial to) this anastomoses the right testicular artery will lie behind the inferior vena cava in the adult.

The Ovarian Arteries

The **ovarian arteries** in the female correspond to the testicular arteries in the male, but they enter the pelvis and supply the ovaries (fig. 749). The origin and course of the first part of each artery are the same as those of the testicular artery, but on arriving at the brim of the true pelvis the artery crosses the upper parts of the external iliac artery and vein, and enters the pelvic cavity. It then runs medially between the two layers of the infundibulopelvic ligament (suspensory ligament of the ovary) and gains the broad ligament of the uterus, where it lies below the uterine tube. At the level of the ovary it passes backwards in the mesovarium and breaks up into branches which are distributed to the ovary. Small branches are given to the ureter and the uterine tube, and one passes to the side of the uterus, and unites with the uterine artery. Other offsets are continued on the round ligament of the uterus, through the inguinal canal, to the skin of the labium majus and the groin.

At an early period of fœtal life, when the testes or ovaries lie by the side of the vertebral column, below the kidneys, the testicular and ovarian arteries are short ; but with the descent of the testicles into the scrotum, and of the ovaries into the pelvis, the arteries are gradually lengthened.

The Phrenic Arteries (fig. 738)

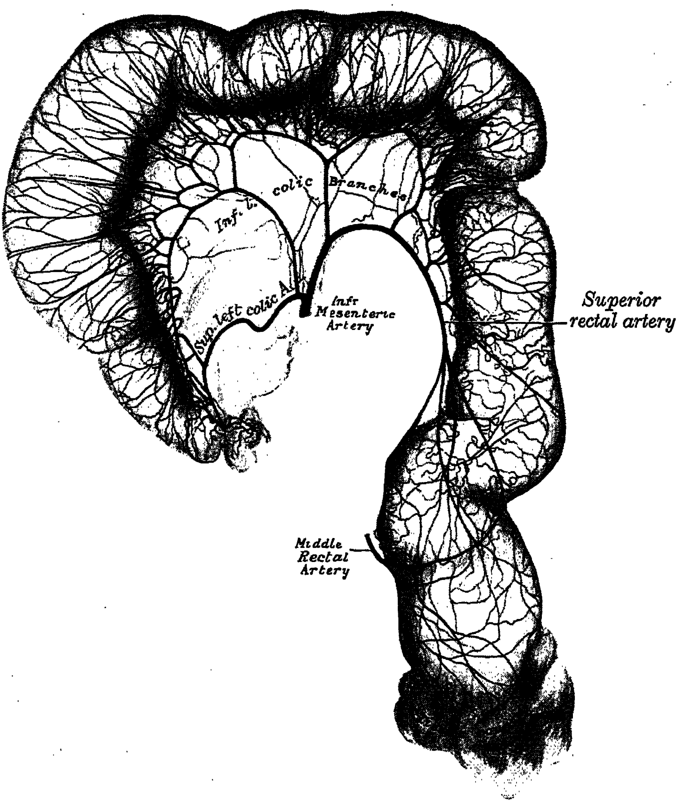
The **phrenic arteries** (inferior phrenic arteries) are two small vessels which supply the Diaphragm. They present much variety in their origins ; they may arise separately from the front of the aorta, immediately above the cœliac artery, or by a common trunk, which may spring either from the aorta or from the cœliac artery ; sometimes one artery is derived from the aorta, and the other from one of the renal arteries. From its origin the artery runs upwards and laterally in front of the crus of the Diaphragm and close to the medial border of the suprarenal gland. The left phrenic passes behind the œsophagus, and runs forwards on the left side of the œsophageal opening. The right phrenic passes behind the inferior vena cava, and along the right side of the opening which transmits that vein. Near the posterior border of the central tendon of the Diaphragm each vessel divides into an internal and an external branch. The internal branch curves forwards, and anastomoses with its fellow of the opposite side in front of the central tendon, and with the musculophrenic and pericardiacophrenic arteries. The external branch passes towards the side of the thorax, and anastomoses with the lower posterior intercostal arteries, and with the musculophrenic artery. The external branch of the right artery gives off a few twigs to the inferior vena cava ; and the left artery sends some branches to the œsophagus. Each vessel gives off two or three small *superior suprarenal branches* to the suprarenal gland of its own side. The liver and the spleen also receive a few twigs from the right and left vessels respectively.

The Lumbar Arteries

The **lumbar arteries** are in series with the posterior (aortic) intercostal arteries and represent persistent intersegmental somatic branches of the aorta

in the embryo (p. 150). Usually four in number on each side, they arise from the back of the aorta, opposite the bodies of the upper four lumbar vertebræ. A fifth pair, small in size, occasionally arises from the median sacral artery; but the lumbar branches of the iliolumbar arteries usually take the place of the fifth pair. The lumbar arteries run laterally and backwards on the bodies of the lumbar vertebræ, deep to the sympathetic trunks, to reach the intervals between the adjacent transverse processes, and are then continued into the abdominal wall. The arteries of the right side pass deep to the inferior vena cava, and the upper two on the right side (the first only on the left side) run deep to the corresponding crus of the Diaphragm. The arteries of both sides

FIG. 746.—The pelvic colon and rectum, showing the distribution of the branches of the inferior mesenteric artery, and their anastomoses. (From a preparation by Hamilton Drummond.)



pass under cover of the tendinous arches which give origin to the Psoas major, and are continued behind this muscle and the lumbar plexus. They then cross the Quadratus lumborum, the upper three arteries running behind, the last usually in front of that muscle. At the lateral border of the Quadratus lumborum they pierce the posterior aponeurosis of the Transversus abdominis, and are carried forwards between this muscle and the Internal oblique. They anastomose with one another and with the lower posterior intercostal, subcostal, iliolumbar, deep circumflex iliac and inferior epigastric arteries.

Branches.—Each lumbar artery gives off a *posterior ramus* which, passing backwards between the transverse processes, is distributed to the muscles and skin of the back. The posterior ramus also furnishes a *spinal branch,* which enters the vertebral canal and supplies its contents, anastomosing with the arteries above and below it, and with the artery of the opposite side. Branches are also given by the lumbar arteries and their posterior rami to the neighbouring muscles.

The Median Sacral Artery (fig. 738)

The **median sacral artery** (middle sacral artery) is a small vessel which arises from the back of the aorta a little above its bifurcation. It descends in the median plane in front of the fourth and fifth lumbar vertebræ, the sacrum and coccyx, and ends in the coccygeal body. At the level of the fifth lumbar vertebra it is crossed by the left common iliac vein, and it frequently gives off on each side a small lumbar artery (*arteria lumbalis ima*). Minute branches are said to pass from it to the posterior surface of the rectum. On the last lumbar vertebra it anastomoses with the lumbar branch of the iliolumbar artery; in front of the sacrum it anastomoses with the lateral sacral arteries, and sends offsets into the anterior sacral foramina.

The Common Iliac Arteries (figs. 738, 747)

The abdominal aorta divides, on the left side of the body of the fourth lumbar vertebra, into the right and left **common iliac arteries.** Each artery passes downwards and laterally, and divides opposite the intervertebral disc between the last lumbar vertebra and the sacrum, into two branches, termed the *external iliac* and *internal iliac* (hypogastric) *arteries*: the former supplies the greater part of the lower limb; the latter, the viscera and parietes of the pelvis, the perineum and the gluteal region.

The **right common iliac artery** (figs. 738, 747), about 5 cm. long, passes obliquely across the body of the last lumbar vertebra. *In front,* it is crossed by sympathetic nerves passing to the hypogastric plexus, and, at its point of division, by the ureter; throughout its course it is covered with the parietal peritoneum, by which it is separated from the coils of the small intestine. *Behind,* it is separated from the bodies of the fourth and fifth lumbar vertebræ and the intervening intervertebral disc by the sympathetic trunk, the terminal parts of the two common iliac veins and the commencement of the inferior vena cava. The obturator nerve, the lumbosacral trunk and the iliolumbar artery are situated more deeply and traverse the fatty tissue which occupies the interval between the last lumbar vertebra and the Psoas major muscle. *Laterally* it is in relation above with the inferior vena cava and the right common iliac vein; below, with the Psoas major. *Medially* its upper part is related to the left common iliac vein.

The **left common iliac artery** (fig. 738), about 4 cm. long, is in relation, *in front,* with the peritoneum, the small intestine, sympathetic nerves passing to the hypogastric plexus, and the superior rectal (superior hæmorrhoidal) artery, and is crossed at its point of bifurcation by the ureter. It rests on the sympathetic trunk and the bodies of the fourth and fifth lumbar vertebræ, and the intervening intervertebral disc. The obturator nerve, the lumbosacral trunk and the iliolumbar artery are placed more deeply. The left common iliac vein lies partly *medial* to, and partly *behind,* the artery; *laterally* the artery is in relation with the Psoas major.

Branches.—The common iliac arteries give off small branches to the peritoneum, Psoas major, ureters, and the surrounding areolar tissue; occasionally they give origin to the iliolumbar or to accessory renal arteries.

Peculiarities.—The points of origin of the common iliac arteries vary according to the bifurcation of the aorta, which in most cases occurs either upon the fourth lumbar vertebra, or upon the disc between it and the fifth.

The common iliac arteries may divide above or below the usual level, and they often make an abrupt downward curve.

The length of the arteries varies from 3·5 to 7·5 cm. In rare instances, the right common iliac has been found wanting, the external and internal iliac arteries arising directly from the aorta.

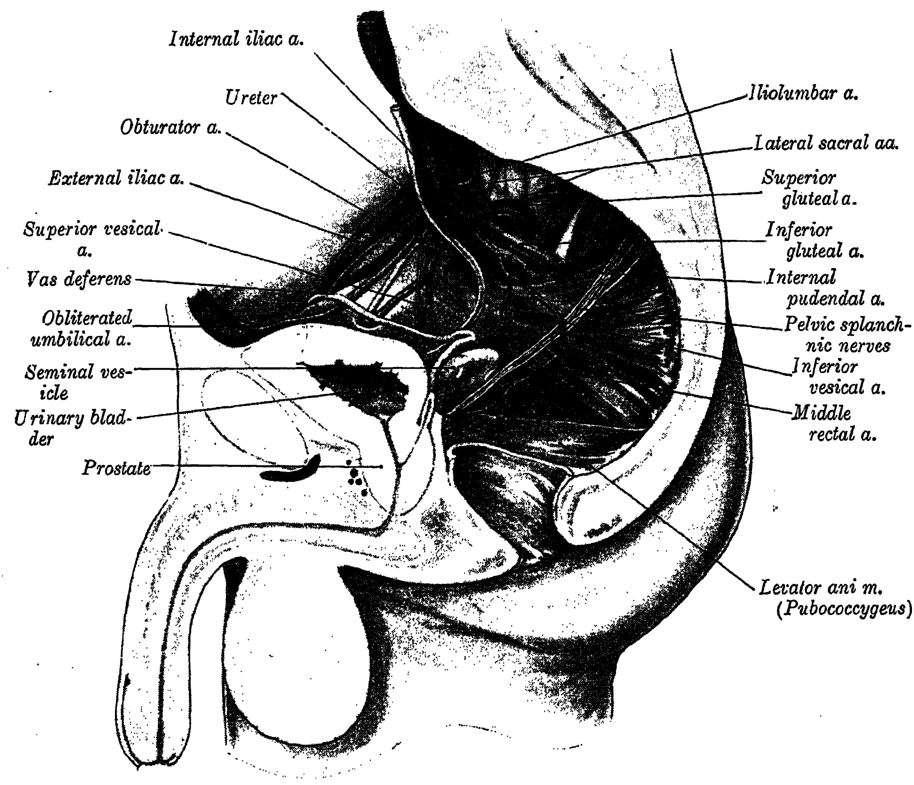
Collateral Circulation.—The principal agents in carrying on the collateral circulation after the application of a ligature to the common iliac are: the anastomoses of the rectal branches of the internal iliac artery with the superior rectal branches from the inferior mesenteric artery; of the uterine, ovarian and vesical arteries of the opposite sides; of the lateral sacral arteries with the median sacral artery; of the inferior epigastric artery

with the internal mammary, lower posterior intercostal and lumbar arteries; of the deep circumflex iliac artery with the lumbar arteries; of the iliolumbar artery with the last lumbar artery; of the obturator artery, by means of its pubic branch, with the vessel of the opposite side and with the inferior epigastric artery.

The Internal Iliac Artery (fig. 747)

The **internal iliac artery** (hypogastric), about 4 cm. long, arises at the bifurcation of the common iliac artery, opposite the sacro-iliac joint; it descends to the upper margin of the greater sciatic foramen, where it divides into an *anterior* trunk, which continues in the line of the parent vessel towards

Fig. 747.—The arteries of the pelvis. Right side.



The internal iliac vein and its tributaries have been removed; the rectum has been divided just above the anal canal and its upper part has been taken away.

the spine of the ischium, and a *posterior* trunk, which passes backwards towards the foramen.

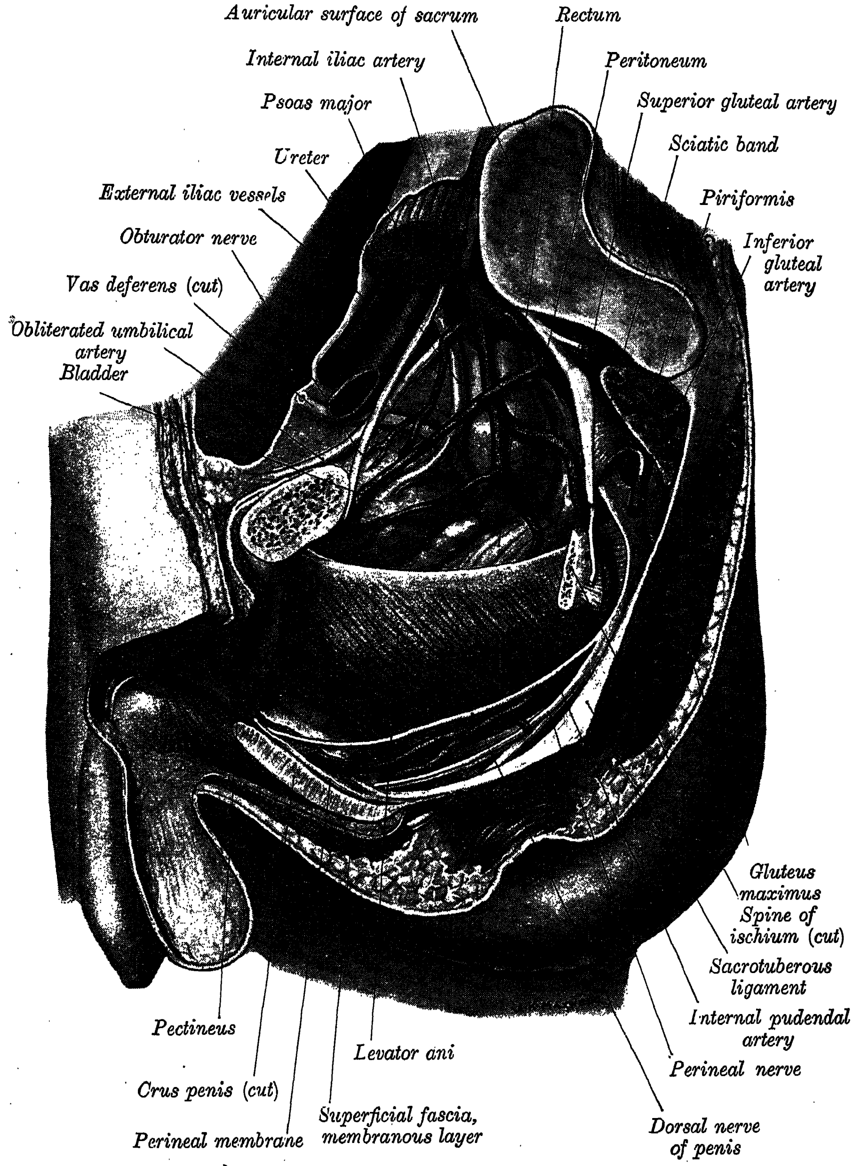
Relations.—It is in relation *in front* with the ureter and, in the female, with the ovary and the fimbriated end of the uterine tube; *behind*, with the internal iliac vein, the lumbosacral nerve-trunk and the sacro-iliac joint; *laterally*, near its origin, with the external iliac vein, which lies between it and the Psoas major; lower down, with the obturator nerve; and *medially* with the peritoneum, which separates it from the terminal part of the ileum, on the right side, and the pelvic colon, on the left side, and with some of the tributaries of the internal iliac vein.

In the fœtus, the internal iliac artery is twice as large as the external iliac artery, and is the direct continuation of the common iliac artery. It ascends on the back of the anterior wall of the abdomen to the umbilicus, converging on its fellow of the opposite side. Having passed through the umbilical

opening, the two arteries, now termed *umbilical*, enter the umbilical cord, where they are coiled round the umbilical vein, and ultimately ramify in the placenta.

At birth, when the placental circulation ceases, only the pelvic portion of the artery remains patent and constitutes the internal iliac artery and the first

FIG. 748.—A dissection of the pelvic contents from the left side.



NOTE.—Most of the left hip-bone has been removed together with the Obturator internus muscle. The Sciatic nerve has been cut away close to its origin from the sacral plexus.

part of the superior vesical artery of the adult; the remainder of the vessel is converted into a fibrous cord, termed the *lateral umbilical ligament*, which extends from the pelvis to the umbilicus.

Peculiarities.—The lengths of the internal and common iliac arteries bear an inverse proportion to each other.

The place of division of the internal iliac artery varies between the upper margin of the sacrum and the upper border of the greater sciatic foramen.

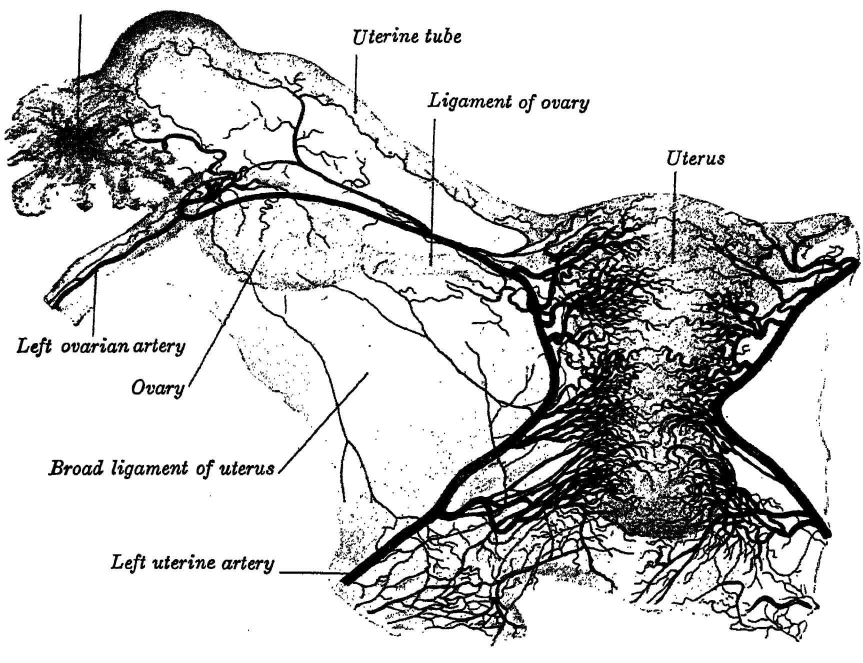
The branches of the internal iliac artery are :

From the Anterior Trunk.
- Superior vesical.
- Inferior vesical.
- Middle rectal.
- Uterine } *In the female.*
- Vaginal }
- Obturator.
- Internal pudendal.
- Inferior gluteal.

From the Posterior Trunk.
- Iliolumbar.
- Lateral sacral.
- Superior gluteal.

The **superior vesical artery** (fig. 747) supplies numerous branches to the upper part of the bladder. From one of these a slender vessel, named the *artery to the vas deferens*, frequently takes origin and accompanies the vas deferens (ductus deferens) in its course to the testis, where it anastomoses with the testicular

FIG. 749.—The left uterine and ovarian arteries of an unmarried girl aged 17½ years. Posterior aspect. (From a preparation by Hamilton Drummond.)



artery. Other branches supply the ureter. The first part of the superior vesical artery is the proximal, patent portion of the fœtal umbilical artery.

The **inferior vesical artery** (fig. 747) frequently arises in common with the middle rectal artery, and is distributed to the fundus of the bladder, the prostate, the seminal vesicles and the lower part of the ureter. The branches to the prostate communicate with the corresponding vessels of the opposite side. The inferior vesical artery gives origin to the artery to the vas deferens when that vessel does not arise from one of the superior vesical branches.

The **middle rectal artery** (middle hæmorrhoidal artery) (figs. 746, 747) usually arises with the preceding vessel. It is distributed to the muscular coats of the rectum, anastomosing with the superior and inferior rectal arteries. It gives offsets to the seminal vesicles and prostate, which anastomose with branches of the inferior vesical artery.

The **uterine artery** (fig. 749) runs medially on the Levator ani and towards the cervix uteri ; about 2 cm. from the cervix *it crosses above and in front of the ureter*—to which it supplies a small branch—and above the lateral fornix of the

vagina. Reaching the side of the uterus it ascends in a tortuous manner between the two layers of the broad ligament to the junction of the uterine tube and uterus. It then runs laterally towards the hilum of the ovary, and ends by joining with the ovarian artery. It supplies branches to the cervix uteri and others which descend on the vagina; the latter anastomose with branches of the vaginal arteries and form with them two median longitudinal vessels—the *azygos arteries of the vagina*—one of which descends in front of, and the other behind, the vagina. It supplies numerous branches to the body of the uterus, and from its terminal portion twigs are distributed to the uterine tube and the round ligament of the uterus.

The **vaginal artery** usually corresponds to the inferior vesical in the male; it descends upon the vagina, supplying its mucous membrane, and sends branches to the bulb of the vestibule, the fundus of the bladder and the contiguous part of the rectum. It assists in forming the azygos arteries of the vagina, and is frequently represented by two or three branches.

The **obturator artery** (fig. 747) passes forwards and downwards on the lateral wall of the pelvis, to the upper part of the obturator foramen, and, escaping from the pelvic cavity through the obturator canal, divides into an anterior and a posterior branch. In the pelvic cavity this vessel is in relation, laterally, with the obturator fascia, which separates it from the Obturator internus muscle; medially, it is crossed by the ureter and the vas deferens, which separate it from the parietal pelvic peritoneum; in the nullipara the ovary is a medial relation. The obturator nerve is above the vessel, and the obturator vein below it.

Branches.—Inside the pelvis, the obturator artery gives off (*a*) **iliac branches** to the iliac fossa; these supply the bone and the Iliacus, and anastomose with the iliolumbar artery; (*b*) a **vesical branch** which runs medially to the bladder, and may replace the inferior vesical branch of the internal iliac artery; and (*c*) a **pubic branch** which springs from the vessel just before it leaves the pelvic cavity; this branch ascends upon the back of the pubis and anastomoses with the corresponding vessel of the opposite side, and with the pubic branch of the inferior epigastric artery.

Outside the pelvis, the obturator artery divides, at the upper margin of the obturator foramen, into an anterior and a posterior branch, which encircle the foramen under cover of the Obturator externus.

The **anterior branch** runs forwards on the outer surface of the obturator membrane and then curves downwards along the anterior margin of the foramen. It supplies branches to the Obturator externus, Pectineus, Adductores and Gracilis, and anastomoses with the posterior branch and with the medial circumflex femoral artery.

The **posterior branch** follows the posterior margin of the foramen and turns forwards on the ramus of the ischium where it anastomoses with the anterior branch. It gives twigs to the muscles attached to the ischial tuberosity and anastomoses with the inferior gluteal artery. It also supplies an *acetabular branch* which enters the hip-joint through the acetabular notch, ramifies in the fat of the acetabular fossa, and sends a twig along the ligamentum capitis femoris to the head of the femur.

Peculiarities.—In about 28 per cent. of subjects the place of the obturator artery is taken by an enlarged pubic branch of the inferior epigastric artery (p. 784); this branch descends almost vertically to the upper part of the obturator foramen. The artery usually lies in contact with the external iliac vein, and on the lateral side of the femoral ring (fig. 750A); in such cases it would not be endangered in the operation for strangulated femoral hernia. Occasionally, however, it curves along the free margin of the pectineal part of the inguinal ligament (fig. 750B), and if in such circumstances a femoral hernia occurred, the vessel would almost completely encircle, and might constrict, the neck of the hernial sac; moreover, it would be in great danger of being wounded if an operation were performed for strangulation. It sometimes arises from the main stem or from the posterior trunk of the internal iliac artery, or it may spring from the superior gluteal artery: occasionally it arises from the external iliac artery.

The **internal pudendal artery** (figs. 747, 748, 751), the smaller of the two terminal branches of the anterior trunk of the internal iliac artery, supplies the external organs of generation. Though the course of the artery is the same in the two sexes, the vessel is smaller in the female than in the male, and the distribution of its branches somewhat different.

The **internal pudendal artery in the male** runs downwards and laterally to the lower border of the greater sciatic foramen, and, passing from the pelvis

between the Piriformis and Coccygeus, enters the gluteal region through the lower part of the greater sciatic foramen ; it then crosses the back of the tip of the ischial spine, and enters the perineum through the lesser sciatic foramen. The artery then traverses the pudendal canal in the lateral wall of the ischiorectal fossa, and so crosses the Obturator internus, being situated about 4 cm. above the lower margin of the ischial tuberosity. It gradually approaches the margin of the ramus of the ischium and passes forwards deep to the perineal membrane (inferior fascia of the urogenital diaphragm) ; it then runs forwards along the medial margin of the inferior ramus of the pubis, and at a distance of about 1·25 cm. behind the inferior pubic ligament it divides into the *dorsal* and *deep arteries of the penis*, but it may pierce the perineal membrane before doing so.

Relations.—Within the pelvis, it lies in front of the Piriformis, the sacral plexus of nerves, and the inferior gluteal artery. As it crosses the ischial spine,

Fig. 750.—Variations in the course of an abnormal obturator artery.

it is covered by the Gluteus maximus ; here the pudendal nerve lies medial, and the nerve to the Obturator internus lateral, to the vessel. In the perineum it lies on the lateral wall of the ischiorectal fossa in the pudendal canal (p. 573) ; it is accompanied by a pair of venæ comitantes and by the pudendal nerve, at first, and then by its terminal branches, viz. the dorsal nerve of the penis, which lies above it, and the perineal nerve, which lies below it.

Branches.—The branches of the internal pudendal artery (figs. 751, 752) are :

Muscular.	Artery of the bulb of the penis.
Inferior rectal.	Urethral.
Scrotal.	Deep artery of the penis.
Transverse perineal.	Dorsal artery of the penis.

The **muscular branches** consist of two sets ; one to the muscles in the pelvis ; the other, as the vessel crosses the ischial spine, to the muscles of the gluteal region.

The **inferior rectal artery** (inferior hæmorrhoidal artery) arises from the internal pudendal as it passes above the ischial tuberosity. Piercing the wall of the pudendal canal (p. 573) it divides into two or three branches which cross the ischiorectal fossa, and are distributed to the muscles and skin of the anal region. In addition they supply the anal canal and send offshoots round the lower edge of the Gluteus maximus to the skin of the buttock. They anastomose with the corresponding vessels of the opposite side, with the superior and middle rectal arteries, and with the transverse perineal artery.

The **scrotal branches** arise from the internal pudendal artery, in front of the preceding branches, cross either superficial, or deep to the Transversus perinei superficialis, and run forwards in the interspace between the Bulbospongiosus and Ischiocavernosus, to both of which they supply branches, and finally are distributed to the skin and Dartos muscle of the scrotum. They often spring from the succeeding artery.

The **transverse perineal artery** arises from the internal pudendal artery, just before it passes deep to the perineal membrane. It runs transversely on the cutaneous surface of the Transversus perinei superficialis, and anastomoses with the corresponding vessel of the opposite side and with the scrotal and inferior rectal arteries. It supplies the Transversus perinei superficialis and the structures between the anus and the bulb of the penis.

The **artery of the bulb of the penis** is a short vessel of relatively large calibre which arises from the internal pudendal artery as it lies deep to the perineal membrane; it passes medially, pierces the membrane, and gives off branches which ramify in the bulb of the penis and in the posterior part of the corpus spongiosum penis (corpus cavernosum urethra). It supplies a small branch to the bulbo-urethral gland.

Fig. 751.—The superficial branches of the internal pudendal artery, in the male.

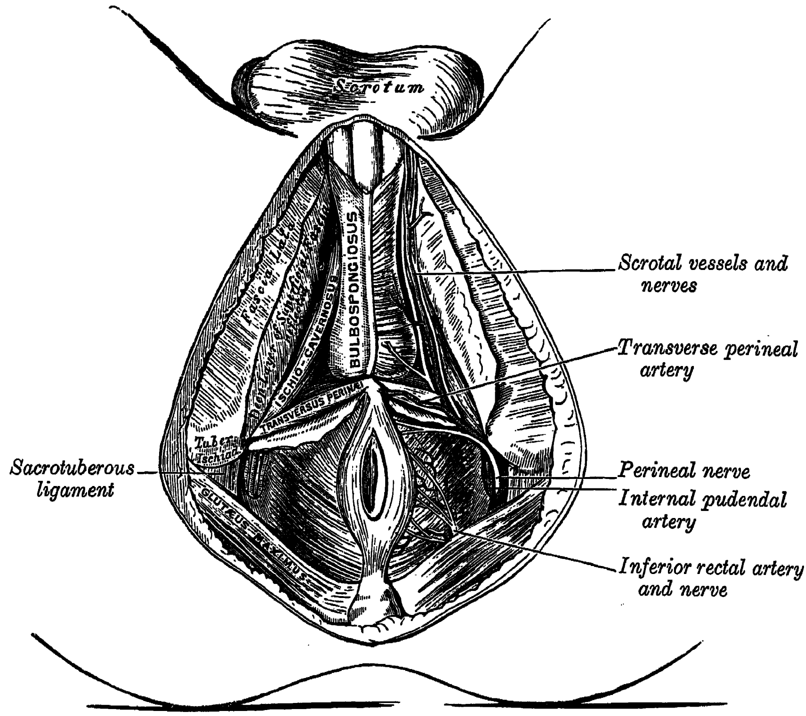
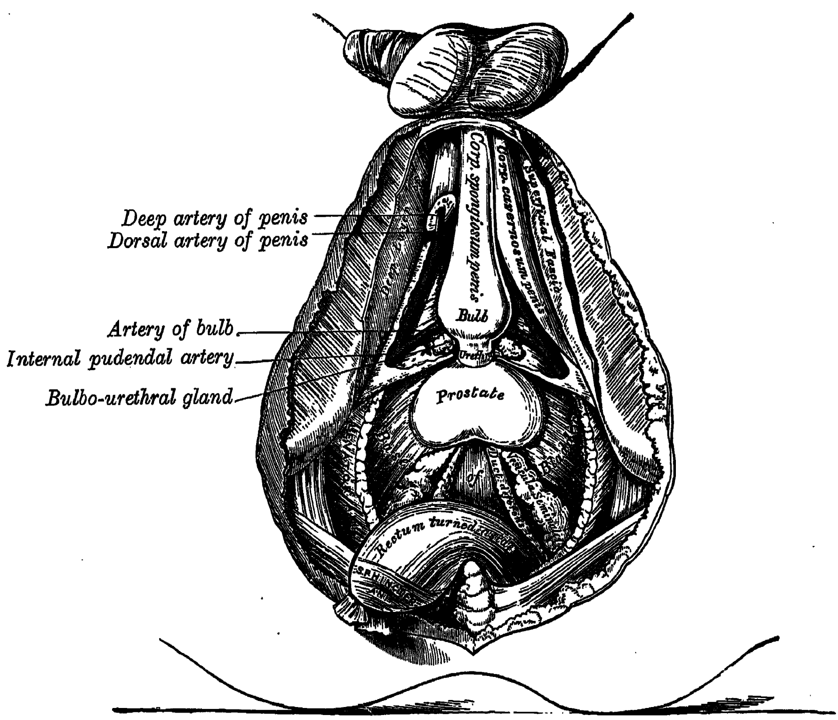


Fig. 752.—The deeper branches of the internal pudendal artery, in the male.



The **urethral artery** arises a short distance in front of the artery of the bulb. It runs forwards and medially, pierces the perineal membrane and enters the corpus spongiosum penis (corpus cavernosum urethræ), in which it is continued forwards to the glans penis.

The **deep artery of the penis**, one of the terminal branches of the internal pudendal artery, arises from that vessel while it is situated deep to the perineal membrane; it pierces the membrane, and, entering the crus penis obliquely, runs forwards in the centre of the corpus cavernosum penis, and supplies its erectile tissue.

The **dorsal artery of the penis** pierces the perineal membrane, and ascends between the crus penis and the pubic symphysis. It then passes between the two layers of the suspensory ligament of the penis, and runs forwards on the dorsum of the penis to the glans, where it divides into two branches, which supply the glans and prepuce. On the penis, it lies between the dorsal nerve and deep dorsal vein, the former being on its lateral side. It supplies the skin and the fibrous sheath of the corpus cavernosum penis, sending branches through the sheath to anastomose with the deep artery of the penis.

The **internal pudendal artery in the female** is smaller than in the male. Its origin and course are similar, and there is considerable analogy in the distribution of its branches. The labial branches supply the labia pudendi; the artery of the bulb is distributed to the bulb of the vestibule and the erectile tissue of the vagina; the deep artery of the clitoris supplies the corpus cavernosum clitoridis; the dorsal artery of the clitoris gives branches to the dorsum of that organ, and ends in the glans and prepuce of the clitoris.

Peculiarities.—The internal pudendal artery is sometimes relatively small, or fails to give off one or two of its usual branches; in such cases the deficiency is supplied by branches derived from an additional vessel, named the *accessory pudendal*, which generally arises from the internal pudendal artery before its exit from the greater sciatic foramen. It passes forwards along the lower part of the bladder and across the side of the prostate to the root of the penis, where it perforates the perineal membrane, and gives off the branches usually derived from the internal pudendal artery. The commonest deficiency is that in which the internal pudendal artery ends as the artery of the bulb, the dorsal and deep arteries of the penis being derived from the accessory pudendal artery. The internal pudendal artery may also end as the transverse perineal, the artery of the bulb being derived, with the other two branches, from the accessory vessel. Occasionally the accessory pudendal artery is derived from one of the other branches of the internal iliac artery, most frequently the inferior vesical or the obturator.

The **inferior gluteal artery** (figs. 748, 753), the larger of the two terminal branches of the anterior trunk of the internal iliac artery (hypogastric artery), is distributed chiefly to the buttock and the back of the thigh. It runs down on the sacral plexus of nerves and the Piriformis, behind the internal pudendal artery, and, passing between the first and second, or second and third, sacral nerves, and then between the Piriformis and Coccygeus it reaches the lower part of the greater sciatic foramen, through which it leaves the pelvis to gain the gluteal region. It then descends in the interval between the greater trochanter of the femur and the tuberosity of the ischium, accompanied by the sciatic and posterior femoral cutaneous nerves, and covered by the Gluteus maximus; it is continued down the back of the thigh, supplying the skin, and anastomosing with branches of the perforating arteries.

Branches.—*Inside the pelvis.* It distributes (*a*) branches to the Piriformis, Coccygeus and Levator ani; (*b*) branches which supply the fat around the rectum, and occasionally take the place of the middle rectal artery; and (*c*) vesical branches to the fundus of the bladder, seminal vesicles and prostate.

Outside the pelvis.—**Muscular branches** supply the Gluteus maximus, the lateral rotators of the thigh, and the muscles attached to the tuberosity of the ischium; they anastomose with the superior gluteal, internal pudendal, obturator and medial circumflex femoral arteries.

Coccygeal branches (fig. 748) run medially, pierce the sacrotuberous ligament, and supply the Gluteus maximus and the structures on the back of the coccyx.

The **arteria comitans nervi ischiadici**, a long slender vessel, accompanies the sciatic nerve for a short distance; it then penetrates it, and runs in its substance to the lower part of the thigh.

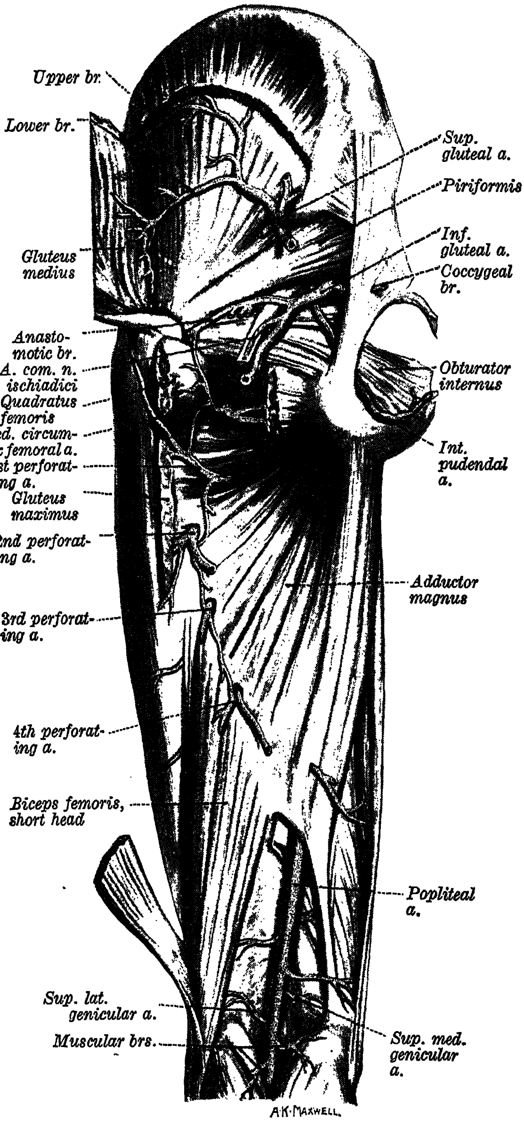
An anastomotic branch, directed obliquely downwards across the lateral rotator muscles of the thigh, assists in forming the so-called *cruciate anastomosis* (p. 791) by joining with the first perforating and the medial and lateral circumflex femoral arteries.

An articular branch, generally derived from the anastomotic, is distributed to the capsule of the hip-joint.

Cutaneous branches are distributed to the skin of the buttock and back of the thigh.

The **iliolumbar artery** (fig. 747), a branch of the posterior trunk of the internal iliac artery, runs upwards and laterally, in front of the sacro-iliac joint and the lumbosacral trunk, and behind the obturator nerve and the external iliac vessels, to the medial border of the Psoas major, behind which it divides into a lumbar and an iliac branch.

FIG. 753.—The arteries of the left gluteal and posterior femoral region.



The **lumbar branch** supplies the Psoas major and Quadratus lumborum, anastomoses with the fourth lumbar artery, and sends a small *spinal branch* through the intervertebral foramen between the fifth lumbar vertebra and the base of the sacrum, into the vertebral canal to supply the cauda equina.

The **iliac branch** supplies the Iliacus; some offsets run between the muscle and the bone, and anastomose with the iliac branches of the obturator artery; one of these enters an oblique canal to supply the bone, while others run along the crest of the ilium, distributing branches to the gluteal and abdominal muscles, and anastomosing in their course with the superior gluteal, circumflex iliac and lateral circumflex femoral arteries.

The **lateral sacral arteries** (fig. 747) arise from the posterior division of the internal iliac (hypogastric) artery; there are usually two, a superior and an inferior. The *superior*, and larger, passes medially, and enters the first or second anterior sacral foramen, supplies branches to the contents of the sacral canal, and, escaping by the corresponding posterior sacral foramen, is distributed to the skin and muscles on the dorsum of the sacrum, anastomosing with the superior gluteal artery. The *inferior* runs obliquely across the front of the Piriformis and the sacral nerves, descends on the front of the sacrum lateral to the sympathetic trunk, and anastomoses over the coccyx with the median sacral artery and the opposite lateral sacral artery. Branches from this vessel enter the anterior sacral foramina, and, after supplying the contents of the sacral canal, escape by the posterior sacral foramina, and are distributed to the muscles and skin on the dorsal surface of the sacrum, anastomosing with the gluteal arteries.

The **superior gluteal artery** (figs. 747, 753) is the largest branch of the internal iliac (hypogastric) artery, and appears to be the continuation of the posterior division of that vessel. It is a short artery which runs backwards between the lumbosacral trunk and the first sacral nerve, or between the first and second sacral nerves, and, passing out of the pelvis through the upper part of the greater sciatic foramen above the upper border of the piriformis, divides into a *superficial* and a *deep branch*. Within the pelvis it gives off a few twigs

to the Piriformis and Obturator internus, and a nutrient artery to the hip-bone.

The *superficial branch* enters the deep surface of the Gluteus maximus, and divides into numerous branches; some of these supply the muscle and anastomose with the inferior gluteal artery; others perforate the tendinous origin of the muscle, supply the skin covering the posterior surface of the sacrum, and anastomose with the posterior branches of the lateral sacral arteries.

The *deep branch* lies under the Gluteus medius and soon splits into a superior and an inferior division. The *superior division* runs along the upper border of the Gluteus minimus to the anterior superior iliac spine, anastomosing with the deep circumflex iliac artery and the ascending branch of the lateral circumflex femoral artery. The *inferior division* crosses the Gluteus minimus obliquely, distributes branches to this muscle and to the Gluteus medius, and anastomoses with the lateral circumflex femoral artery; one branch enters the trochanteric fossa, where it anastomoses with the inferior gluteal and the ascending branch of the medial circumflex femoral artery; other branches pierce the Gluteus minimus and supply the hip-joint.

Collateral Circulation.—The circulation after ligature of the internal iliac artery is carried on by the anastomoses of the uterine and ovarian arteries; of the vesical arteries of the two sides; of the rectal branches of the internal iliac artery with those from the inferior mesenteric artery; of the pubic branch of the obturator artery with the vessel of the opposite side, and with the inferior epigastric and medial circumflex femoral arteries; of the circumflex and perforating branches of the arteria profunda femoris with the inferior gluteal artery; of the superior gluteal artery with the posterior branches of the lateral sacral arteries; of the iliolumbar with the last lumbar artery; of the median sacral artery with the lateral sacral arteries; and of the circumflex iliac with the iliolumbar and superior gluteal arteries.*

THE EXTERNAL ILIAC ARTERY (figs. 747, 754)

The **external iliac artery** is larger than the internal iliac (hypogastric) artery, and runs obliquely downwards and laterally, along the medial border of the Psoas major. It extends from the bifurcation of the common iliac artery to a point behind the inguinal ligament, midway between the anterior superior iliac spine and the symphysis pubis, where it enters the thigh as the femoral artery.

Relations.—*In front and medially* the external iliac artery is in relation with the peritoneum and extraperitoneal tissue, which separate the right artery from the termination of the ileum and frequently the vermiform appendix, and the left artery from the pelvic colon and some coils of the small intestine. The beginning of the artery may be crossed by the ureter; in the female it is crossed by the ovarian vessels. The testicular vessels lie for some distance upon it near its termination, and it is crossed in this situation by the genital (external spermatic) branch of the genitofemoral nerve, the deep circumflex iliac vein, the vas deferens in the male, and the round ligament of the uterus in the female. *Posteriorly* it is separated from the medial border of the Psoas major by the iliac fascia. The external iliac vein lies partly behind the upper part of the artery, but is on the medial side of its lower part. *Laterally* it is related to the Psoas major, from which it is separated by the iliac fascia. Numerous lymphatic vessels and lymph glands lie on the front and sides of the vessel.

Branches.—Besides supplying several small branches to the Psoas major and the neighbouring lymph glands, the external iliac artery gives off the inferior epigastric and deep circumflex iliac branches.

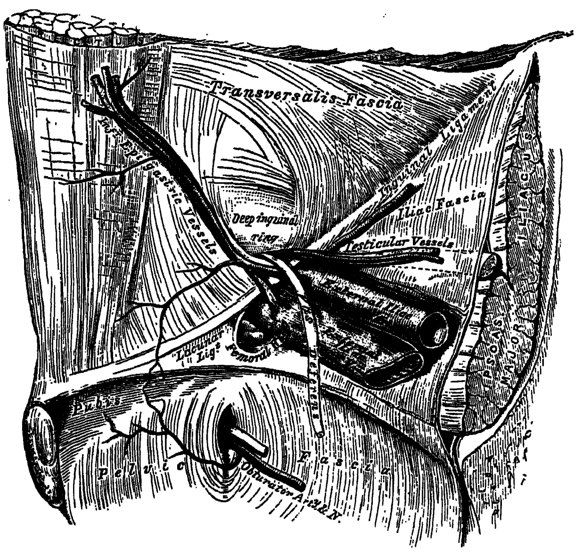
The **inferior epigastric artery** (figs. 604, 754) arises from the external iliac artery, immediately above the inguinal ligament. It curves forwards in the extraperitoneal tissue, and then ascends obliquely along the medial margin of the deep inguinal ring (abdominal inguinal ring); continuing its upward course, it pierces the transversalis fascia, passes in front of the arcuate line (linea semicircularis), and ascends between the Rectus abdominis and the

* For a description of a case in which Owen made a dissection ten years after ligature of the internal iliac artery, see *Med. Chir. Trans.* vol. xvi.

posterior lamella of its sheath. It finally divides into numerous branches, which anastomose, above the umbilicus, with the superior epigastric branch of the internal mammary artery and with the lower posterior intercostal arteries. As the inferior epigastric artery passes obliquely upwards from its origin it lies along the lower and medial margins of the deep inguinal ring, and behind the commencement of the spermatic cord, separated from it by the transversalis fascia. In the male the vas deferens (ductus deferens), and in the female the round ligament of the uterus, winds round the lateral and posterior surfaces of the artery. The inferior epigastric artery supplies the following branches :

The **cremasteric artery** (external spermatic artery) accompanies the spermatic cord, supplies the Cremaster and other coverings of the cord, and anastomoses with the testicular

FIG. 754.—The right inferior epigastric artery, and the relations of the right femoral and deep inguinal rings. Seen from within the abdomen.



artery. In the female the artery is very small and accompanies the round ligament of the uterus.

A **pubic branch** descends along the medial margin of the femoral ring to the back of the pubis, and there anastomoses with the pubic branch of the obturator artery. In about 28 per cent. of subjects the pubic branch is large, and takes the place of the obturator artery (p. 778).

Branches are distributed to the abdominal muscles and the peritoneum, and anastomose with the circumflex iliac and lumbar arteries.

Cutaneous branches perforate the aponeurosis of the External oblique muscle, supply the skin and anastomose with branches of the superficial epigastric artery.

Peculiarities.—The inferior epigastric artery may spring from any part of the external iliac artery between the inguinal ligament and a point 6 cm. above it ; or it may arise below this ligament, from the femoral artery. In the latter case, it ascends in front of the femoral vein. It frequently springs from the external iliac artery, by a common trunk with the abnormal obturator artery. Sometimes it arises from the obturator artery.

Applied Anatomy.—The inferior epigastric artery has important surgical relations, and is one of the principal means, through its anastomosis with the internal mammary, of establishing the collateral circulation after ligature of either the common or external iliac arteries. It lies close to the deep inguinal ring (abdominal inguinal ring), and is therefore *medial* to an oblique inguinal hernia, but *lateral* to a direct inguinal hernia, as these emerge from the abdomen.

The **deep circumflex iliac artery** arises from the lateral side of the external iliac artery nearly opposite the inferior epigastric artery. It ascends obliquely

to the anterior superior iliac spine and behind the inguinal ligament, in a sheath formed by the junction of the transversalis and iliac fasciæ. There it anastomoses with the ascending branch of the lateral circumflex femoral artery. It then pierces the transversalis fascia and passes along the inner lip of the crest of the ilium to about its middle, where it perforates the Transversus abdominis and runs backwards between that muscle and the Internal oblique, to anastomose with the iliolumbar and superior gluteal arteries. Opposite the anterior superior iliac spine it gives off a large *ascending branch* (fig. 602), which runs between the Internal oblique and Transversus, supplying them, and anastomosing with the lumbar and inferior epigastric arteries.

Collateral Circulation.—The principal anastomoses by which the collateral circulation is established, after ligature of the external iliac artery, are: the iliolumbar with the circumflex iliac arteries; the superior gluteal with the lateral circumflex femoral artery; the obturator with the medial circumflex femoral artery; the inferior gluteal with the circumflex and first perforating branches of the arteria profunda femoris; and the internal pudendal with the external pudendal arteries. When the obturator artery arises from the inferior epigastric artery, it is supplied with blood by branches from either the internal iliac, the lateral sacral or the internal pudendal arteries. The inferior epigastric artery receives its supply from the internal mammary and lower posterior intercostal arteries, and from the internal iliac artery by the anastomoses of its branches with the obturator artery.*

THE ARTERIES OF THE LOWER LIMB

The chief artery of the lower limb is a direct continuation of the external iliac. It extends from the level of the inguinal ligament to the lower border of the Popliteus, where it divides into the anterior and posterior tibial arteries. Its upper part is named the femoral artery; its lower, the popliteal artery.

The Femoral Artery (figs. 758, 759)

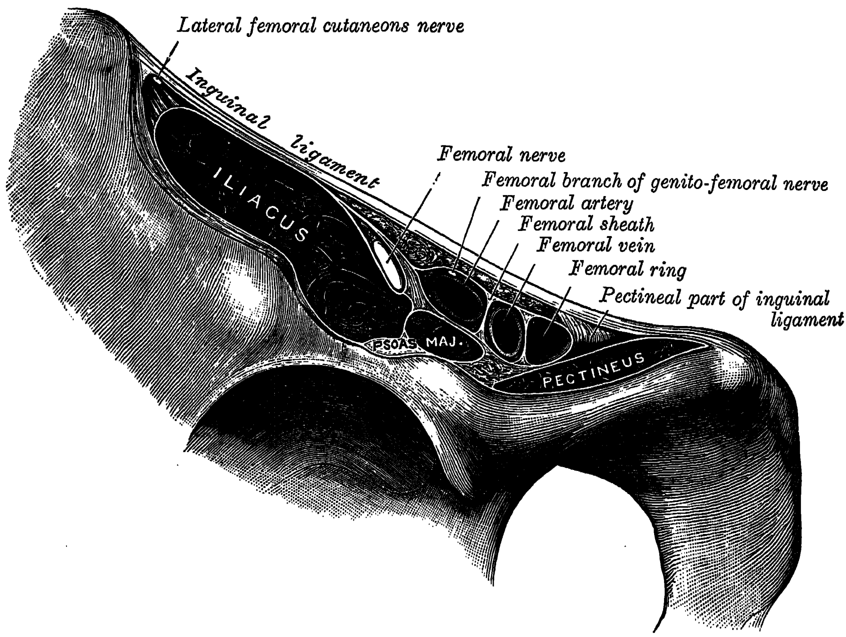
The **femoral artery** is the continuation of the external iliac artery. It begins behind the inguinal ligament, midway between the anterior superior iliac spine and the symphysis pubis, and passes down the front and medial side of the thigh. It ends at the junction of the middle with the lower one-third of the thigh, where it passes through an opening in the Adductor magnus to become the popliteal artery. The upper part of the femoral artery is contained in the *femoral triangle*, the lower part in the *subsartorial canal* (adductor canal). The first 3 cm. or 4 cm. of the vessel are enclosed, together with the femoral vein, in the *femoral sheath.*

The **femoral sheath** (fig. 755) is formed by a prolongation downwards, behind the inguinal ligament, of the fasciæ lining the abdomen, the transversalis fascia being continued down in front of the femoral vessels and the iliopectineal fascia behind them. The sheath has the form of a short funnel, the wide end of which is directed upwards, while the lower, narrow end fuses with the fascial investment of the vessels, about 3 or 4 cm. below the inguinal ligament. The lateral wall of the sheath is vertical and is perforated by the femoral branch of the genitofemoral nerve; the medial wall is directed obliquely downwards and laterally, and is pierced by the long saphenous vein and by some lymphatic vessels. Like the carotid sheath (p. 537) in structure, the femoral sheath consists of a mass of connective tissue in which the femoral vessels are imbedded. It is customary to describe three compartments; of these, the lateral contains the femoral artery, the intermediate the femoral vein, while the medial and smallest compartment is named the *femoral canal*, and contains some lymph vessels and a lymph gland, imbedded in a small amount of areolar tissue. The femoral canal is conical and measures 1·25 cm. in length; its base, directed upwards and named the *femoral ring*, is oval in form, its long or transverse

* Sir Astley Cooper described in vol. i. of the *Guy's Hospital Reports* the dissection of a limb eighteen years after successful ligature of the external iliac artery.

diameter measuring 1·25 cm. The femoral ring (fig. 755) is bounded in front by the inguinal ligament, behind by the Pectineus covered by its fascia, medially by the crescentic base of the pectineal part of the inguinal ligament (lacunar ligament), and laterally by the femoral vein. The spermatic cord in the male, and the round ligament of the uterus in the female, lie immediately above the anterior margin of the ring, while the inferior epigastric vessels are close to its upper and lateral angle. The ring is larger in women than in men. This difference is accounted for partly by the greater breadth of the female pelvis and partly by the smaller size of the femoral vessels. The femoral ring is closed by a somewhat condensed portion of the extraperitoneal tissue, named the *femoral septum,* which contains a small lymph gland and is covered

Fig. 755.—The structures passing behind the inguinal ligament. Seen from below.



by the parietal layer of the peritoneum. The femoral septum is pierced by numerous lymph vessels passing from the deep inguinal to the external iliac lymph glands, and the parietal peritoneum immediately above it presents a slight depression named the *femoral fossa.*

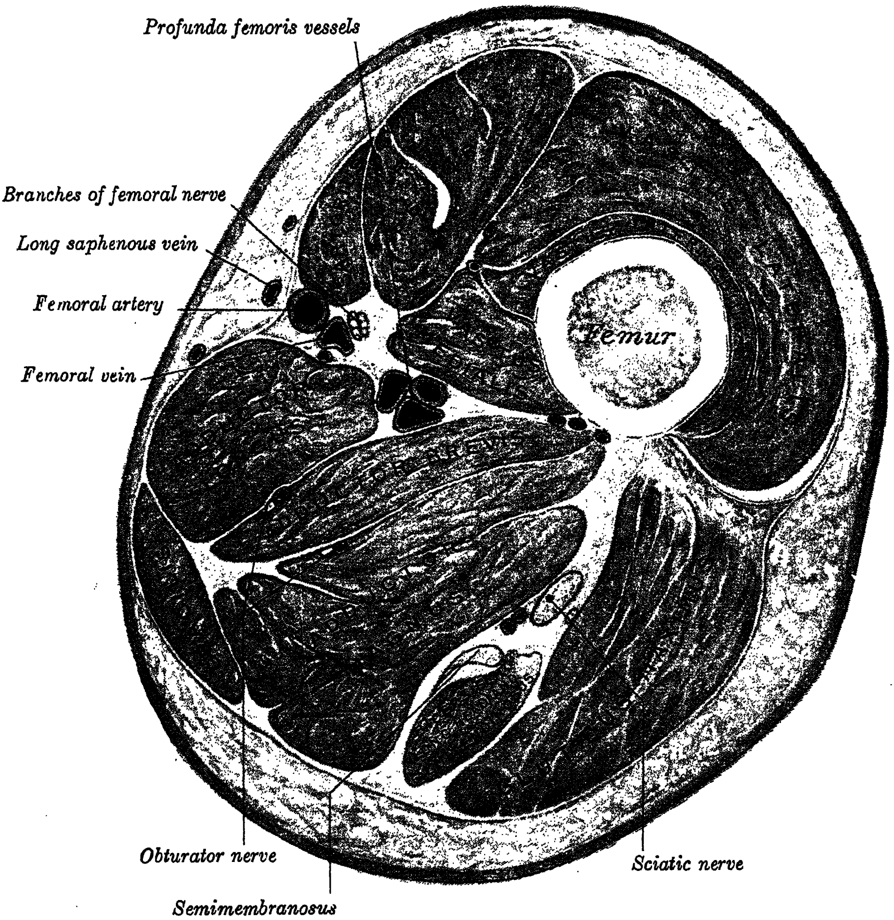
The **femoral triangle** (fig. 758) corresponds to the depression seen immediately below the fold of the groin. Its apex is directed downwards, and the sides are formed, laterally by the medial margin of the Sartorius, medially by the medial margin of the Adductor longus, above by the inguinal ligament. The floor of the triangle is gutter-like and is formed laterally by the Iliacus and Psoas major, and medially by the Pectineus and Adductor longus. The femoral vessels, which extend from near the middle of its base to its apex, lie in the deepest part of the gutter. On the lateral side of the femoral artery the femoral nerve divides into its branches. Besides the vessels and nerves, this triangle contains some fat and lymph glands.

The **subsartorial canal** (adductor canal) (fig. 757) is an aponeurotic tunnel in the middle one-third of the thigh, extending from the apex of the femoral triangle to the opening in the Adductor magnus through which the femoral vessels pass from the front of the thigh to the popliteal fossa. It is triangular on transverse section, and is bounded, in front and laterally, by the Vastus medialis; behind, by the Adductor longus above, and Adductor magnus below; and is roofed by a strong aponeurosis which extends from these muscles, across

the femoral vessels, to the Vastus medialis. The Sartorius lies on the aponeurotic roof. The canal contains the femoral artery and vein, and the saphenous nerve; the nerve to the Vastus medialis traverses the proximal part of the adductor canal, and then enters its muscle.

The relations of the femoral artery.—In the *femoral triangle* (fig. 758) the artery is covered with the skin and superficial fascia, the superficial inguinal lymph glands, the superficial layer of the fascia lata and the anterior part of the femoral sheath, and is crossed by the superficial circumflex iliac vein, which runs in the superficial fascia. The femoral branch of the genitofemoral nerve

FIG. 756.—A transverse section through the thigh at the level of the apex of the femoral triangle. About four-fifths of the natural size.



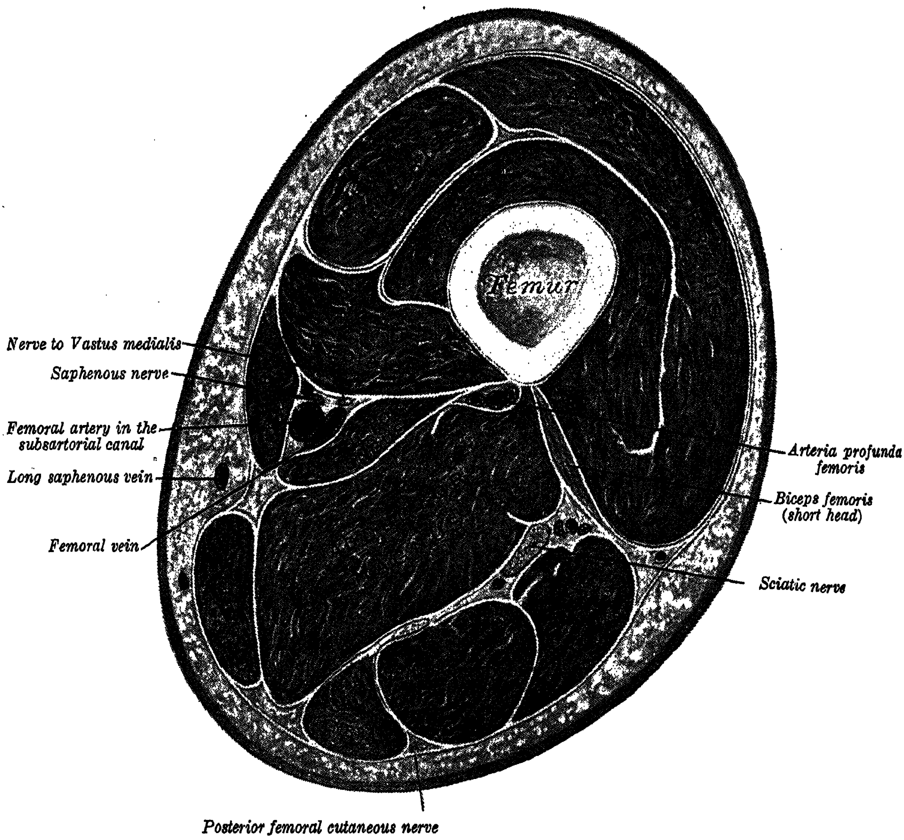
courses for a short distance within the lateral compartment of the femoral sheath, and lies at first in front of and then lateral to the artery. Near the apex of the femoral triangle the medial cutaneous nerve of the thigh crosses the artery from its lateral to its medial side.

Behind, the artery lies in contact with the posterior part of the femoral sheath, by which it is separated from the tendon of the Psoas major, the Pectineus and the Adductor longus, in that order from above downwards. The artery is separated from the capsule of the hip-joint by the tendon of the Psoas major, from the Pectineus by the femoral vein and profunda vessels, and from the Adductor longus by the femoral vein—the profunda vessels having passed posterior to the Adductor longus. The nerve to the Pectineus passes medially behind the upper end of the artery. *Laterally* the artery is

related to the femoral nerve. The femoral vein is medial to the artery in the upper part of the femoral triangle, and posterior to the artery in the lower part.

In the *subsartorial canal* (figs. 757, 759) the femoral artery is more deeply situated, being covered with the skin, the superficial and deep fasciæ, the Sartorius and the fibrous roof of the canal. The saphenous nerve is at first on the lateral side of the artery; it then lies in front of it, and below is placed on its medial side. Behind, the artery is related to the Adductor longus above, and Adductor magnus below; in front and lateral to it is the Vastus medialis.

Fig. 757.—A transverse section through the middle of the thigh. Four-fifths of natural size.



The femoral vein lies posterior to the upper, and lateral to the lower, part of the artery.

Peculiarities.—Several instances are recorded where the femoral artery divided, below the origin of the arteria profunda femoris, into two trunks, which reunited near the opening in the Adductor magnus; a few have been reported where the femoral artery was absent, its place being supplied by the inferior gluteal artery, which accompanied the sciatic nerve to the popliteal fossa; in these the external iliac artery was small, and ended as the arteria profunda femoris. The femoral vein is occasionally placed along the medial side of the artery throughout the entire extent of the femoral triangle; or it may be duplicated so that a large vein is placed on each side of the artery for a greater or lesser distance.

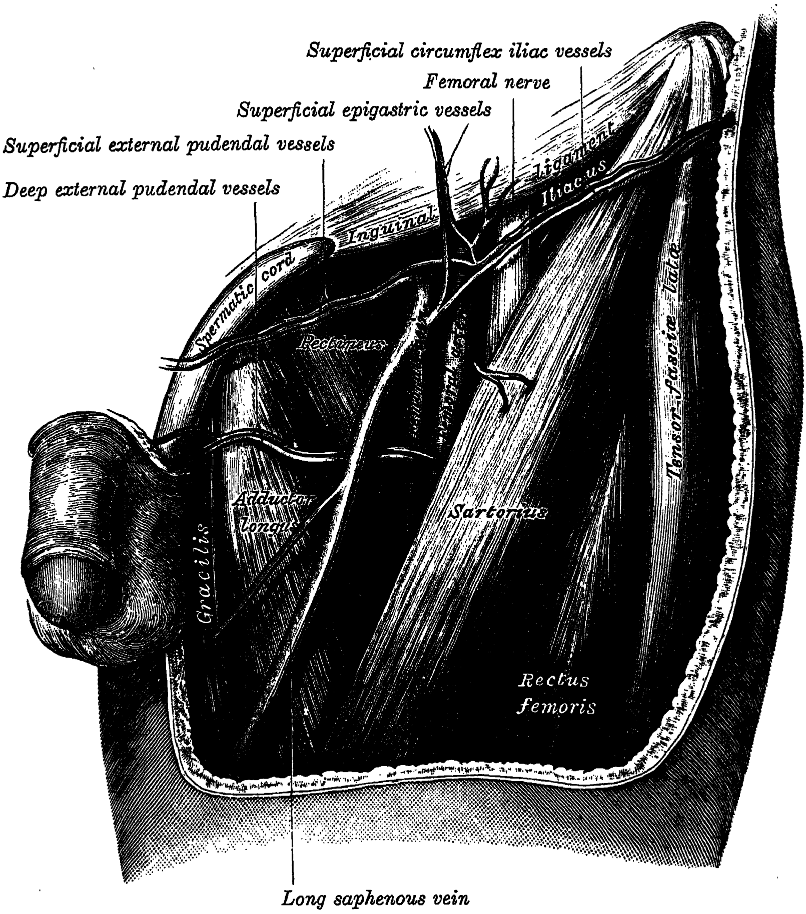
Applied Anatomy.—Compression of the femoral artery is most effectually made immediately below the inguinal ligament. In this situation the artery is superficial, and is separated from the superior ramus of the pubis by the Psoas major; here digital compression will effectually control the circulation through it. The vessel may also be controlled in the middle third of the thigh by a tourniquet which presses the vessel against the medial side of the femur.

Branches.—The branches of the femoral artery are :

1. Superficial epigastric.
2. Superficial circumflex iliac.
3. Superficial external pudendal.
4. Deep external pudendal.
5. Muscular.
6. Profunda femoris.
7. Descending genicular.

1. The **superficial epigastric artery** (fig. 758) arises from the front of the femoral artery about 1 cm. below the inguinal ligament, and, piercing the

FIG. 758.—The left femoral triangle.



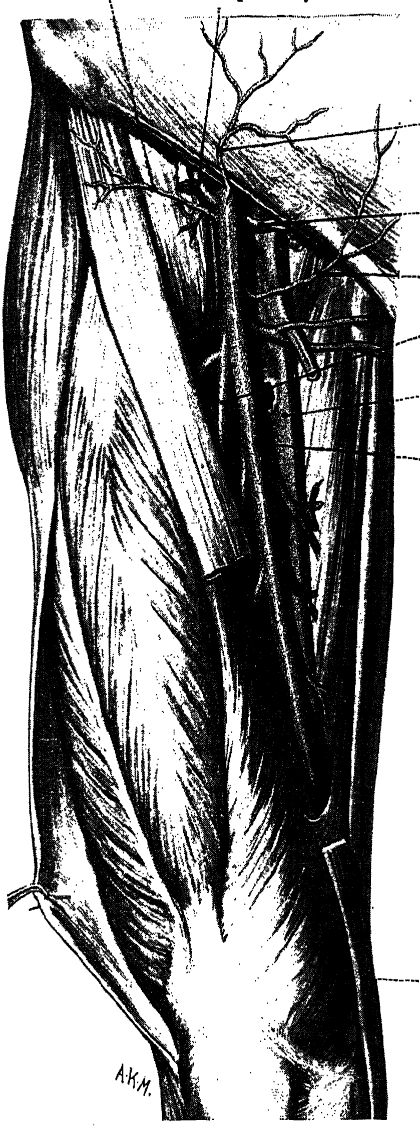
femoral sheath and the cribriform fascia, ascends in front of the inguinal ligament, and between the two layers of the superficial fascia of the abdominal wall nearly as far as the umbilicus. It distributes branches to the superficial inguinal lymph glands, the superficial fascia and the skin ; it anastomoses with branches of the inferior epigastric artery, and with its fellow of the opposite side.

2. The **superficial circumflex iliac artery** (fig. 758), the smallest of the superficial branches of the femoral artery, arises close to the preceding vessel, and running laterally, parallel with the inguinal ligament, pierces the fascia lata near the anterior superior iliac spine ; it gives branches to the skin, superficial fascia and superficial inguinal lymph glands, and anastomoses with the deep circumflex iliac, the superior gluteal and the lateral circumflex femoral arteries.

3. The **superficial external pudendal artery** (fig. 758) arises from the

medial side of the femoral artery, close to the preceding vessels. After piercing the femoral sheath and the cribriform fascia, it courses medially, across the spermatic cord (or round ligament of the uterus in the female), to be distributed to the skin on the lower part of the abdomen, the penis and scrotum in the male, and the labium majus in the female, anastomosing with branches of the internal pudendal artery.

Fig. 759.—The right femoral vessels.



4. The **deep external pudendal artery** (fig. 758) passes medially across the Pectineus and either in front of or behind the Adductor longus; it is covered by the fascia lata, which it pierces at the medial side of the thigh, and thereafter it is distributed, in the male, to the skin of the scrotum and perineum, in the female to the labium majus; its branches anastomose with the scrotal (or labial) branches of the internal pudendal artery.

5. **Muscular branches** are supplied by the femoral artery to the Sartorius, Vastus medialis and the Adductor muscles.

6. The **arteria profunda femoris** (figs 757, 759) is a large vessel arising from the lateral side of the femoral artery, about 3·5 cm. below the inguinal ligament. At first lateral to the femoral artery the profunda then runs behind it and the femoral vein to the medial side of the femur, and is continued downwards behind the Adductor longus. It ends at the lower one-third of the thigh in a small branch which pierces the Adductor magnus and anastomoses with the superior muscular branches of the popliteal artery. The terminal part of the profunda is sometimes named the *fourth perforating artery*.

Relations. — *Behind*, from above downwards, it is related to the Iliacus, Pectineus, Adductor brevis, and Adductor magnus. *In front*, it is separated from the femoral artery by the femoral and profunda veins above, and by the Adductor longus below. *Laterally*, the origin of the Vastus medialis intervenes between it and the femur.

Peculiarities.—This vessel sometimes arises from the medial side, more rarely from the back of the femoral artery. When it arises from the medial side, it may cross in front of the femoral vein and then pass backwards round its medial side. In most cases it arises between 2·25 cm. and 5 cm. below the inguinal ligament; in a few cases the distance is less than 2·25 cm.; more rarely it arises opposite the ligament. Occasionally the distance between the origin of the vessel and the inguinal ligament exceeds 5 cm.

The arteria profunda femoris gives off the following branches :

Lateral circumflex femoral.	Perforating.
Medial circumflex femoral.	Muscular.

The **lateral circumflex femoral artery** (fig. 759) arises from the lateral side of the profunda artery, passes laterally between the divisions of the femoral nerve and behind the Sartorius and Rectus femoris, and divides into ascending, transverse and descending branches. Occasionally it arises from the femoral artery.

The *ascending branch* passes upwards along the trochanteric line, under cover of the Tensor fasciæ latæ, to the lateral part of the hip ; it anastomoses with the terminal branches of the superior gluteal and deep circumflex iliac arteries, and sends a twig to the hip-joint between the medial and lateral parts of the iliofemoral ligament.

The *descending branch*, which may arise as an independent branch direct from the profunda femoris or, sometimes, from the femoral artery, runs downwards, behind the Rectus femoris, along the anterior border of the Vastus lateralis, to which it gives offsets ; one long branch descends in the latter muscle as far as the knee, and anastomoses with the lateral superior genicular branch of the popliteal artery. It is accompanied by the nerve to the Vastus lateralis.

The *transverse branch*, the smallest, passes laterally over the Vastus intermedius, pierces the Vastus lateralis, and winds round the femur, just below the greater trochanter, anastomosing on the back of the thigh with the medial circumflex femoral, inferior gluteal, and first perforating arteries (*cruciate anastomosis*).

The **medial circumflex femoral artery** usually arises from the posteromedial aspect of the profunda artery, but frequently springs from the femoral artery. It gives off *muscular branches* to the adductor muscles and then winds round the medial side of the femur, passing first between the Pectineus and Psoas major, and then between the Obturator externus and Adductor brevis, and finally appears between the Quadratus femoris and the upper border of the Adductor magnus, where it divides into transverse and ascending branches. The *transverse branch* takes part in the formation of the cruciate anastomoses. The *ascending branch* runs obliquely upwards upon the tendon of the Obturator externus and in front of the Quadratus femoris towards the trochanteric fossa, where it anastomoses with twigs from the gluteal arteries. An *acetabular branch* arises from the medial circumflex femoral artery at the upper border of Adductor brevis and enters the hip-joint below the transverse acetabular ligament, in company with the acetabular branch from the obturator artery; it supplies the fat in the acetabular fossa, and is continued along the ligamentum capitis femoris to the head of the femur.

The **perforating arteries** (fig. 753), usually three in number, are so named because they perforate the insertion of the Adductor magnus to reach the back of the thigh. They pass backwards close to the linea aspera of the femur under cover of small tendinous arches in the insertion of the muscle, and give off muscular, cutaneous and anastomosing branches. Reduced in size, they pass deep to the short head of the Biceps femoris (the first usually pierces the insertion of the Gluteus maximus), pierce the lateral intermuscular septum and enter the Vastus lateralis. The first perforating artery is given off above the Adductor brevis, the second in front of that muscle, and the third immediately below it.

The *first perforating artery* passes backwards between the Pectineus and Adductor brevis (sometimes it perforates the latter muscle); it then pierces the Adductor magnus close to the linea aspera. It gives branches to the Adductor brevis, Adductor magnus, Biceps femoris and Gluteus maximus, and anastomoses with the inferior gluteal, medial and lateral circumflex femoral, and second perforating arteries.

The *second perforating artery*, larger than the first, but frequently arising in common with it, pierces the insertions of the Adductor brevis and Adductor magnus, and divides into ascending and descending branches, which supply the posterior femoral muscles, anastomosing with the first and third perforating arteries. The *nutrient artery* of the femur is usually given off from this artery; when two nutrient arteries exist, they usually spring from the first and third perforating vessels.

The *third perforating artery* is given off below the Adductor brevis; it pierces the insertion of the Adductor magnus, and divides into branches which supply the posterior

femoral muscles, and anastomose above with the higher perforating arteries, and below with the termination of the profunda and the muscular branches of the popliteal. The nutrient artery of the femur may arise from this branch.

The termination of the profunda artery, already described, is sometimes called the *fourth perforating artery.*

The perforating arteries form a double chain of anastomosing vessels, (*a*) in the muscles and (*b*) close to the linea aspera.

Numerous **muscular branches** arise from the arteria profunda femoris ; some of these end in the Adductors, others pierce the Adductor magnus, give branches to the hamstrings, and anastomose with the medial circumflex femoral artery and with the superior muscular branches of the popliteal artery.

The anastomosis on the back of the thigh. An important chain of anastomoses stretches from the gluteal region to the popliteal fossa, and is formed from above downwards, as follows : (*a*) the gluteal arteries anastomose with the terminal branches of the medial circumflex femoral artery, (*b*) the circumflex femoral arteries with the first perforating artery, (*c*) the perforating arteries with each other, and (*d*) the fourth perforating artery with the superior muscular branches of the popliteal artery.

7. **The descending genicular artery** (highest genicular artery) (figs. 759, 762) arises from the femoral just before it passes through the opening in the Adductor magnus, and immediately gives off a saphenous branch, and then descends in the substance of the Vastus medialis, and in front of the tendon of the Adductor magnus, to the medial side of the knee, where it anastomoses with the medial superior genicular artery. It supplies *muscular branches* to the Vastus medialis and Adductor magnus, and gives off *articular branches*, which take part in the anastomosis round the knee-joint. One of the articular branches crosses above the patellar surface of the femur, forming an anastomotic arch with the lateral superior genicular artery, and supplying branches to the knee-joint.

The *saphenous branch* pierces the lower part of the roof of the subsartorial canal and accompanies the saphenous nerve to the medial side of the knee. It passes between the Sartorius and Gracilis, and is distributed to the skin of the upper and medial part of the leg, anastomosing with the medial inferior genicular artery.

Collateral Circulation.—After ligature of the femoral artery above the origin of the profunda femoris artery, the main channels for carrying on the circulation are the following anastomoses : (1) the superior and inferior gluteal branches of the internal iliac (hypogastric) artery with the medial and lateral circumflex femoral and first perforating branches of the arteria profunda femoris ; (2) the obturator branch of the internal iliac artery with the medial circumflex femoral of the arteria profunda femoris ; (3) the internal pudendal branch of the internal iliac artery with the superficial and deep external pudendal branches of the femoral artery ; (4) the deep circumflex iliac branch of the external iliac artery with the lateral circumflex femoral branch of the arteria profunda femoris and the superficial circumflex iliac branch of the femoral artery ; and (5) the inferior gluteal branch of the internal iliac artery with the perforating branches of the arteria profunda femoris.

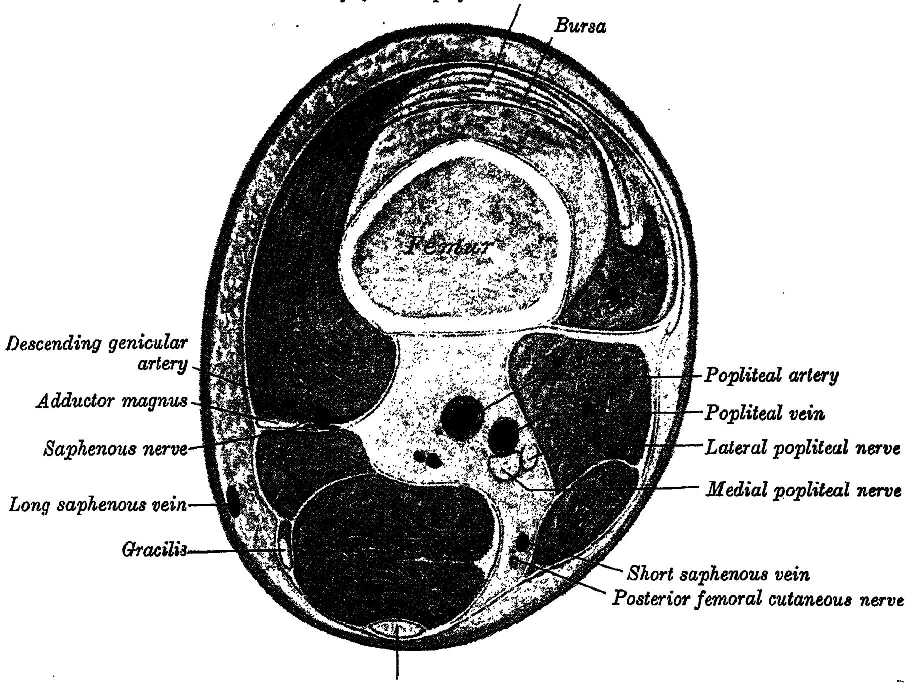
The Popliteal Fossa (figs. 760, 761)

Boundaries.—The **popliteal fossa,** or **space,** is a lozenge-shaped space at the back of the knee-joint. Laterally, it is bounded by the Biceps femoris above, and by the Plantaris and the lateral head of the Gastrocnemius below ; medially it is limited by the Semitendinosus and Semimembranosus above, and by the medial head of the Gastrocnemius below. The floor is formed by the popliteal surface of the femur, the oblique posterior ligament of the knee-joint, the back of the upper end of the tibia and the fascia covering the Popliteus ; the fossa is covered by the popliteal fascia.

Contents (figs. 760, 761).—When its boundaries are undisturbed, the popliteal fossa is only about 2·5 cm. wide, and very little can be seen of its contents. This is especially the case in the lower part of the space where the two heads of the Gastrocnemius lie in contact with each other. If, however, the boundaries be drawn apart the fossa is seen to contain the popliteal vessels, the

medial and lateral popliteal (tibial and the common peroneal) nerves, the termination of the short saphenous vein, the lower part of the posterior femoral cutaneous nerve, the articular branch from the obturator nerve, a few small lymph glands and a considerable quantity of fat. The medial popliteal (tibial) nerve descends through the middle of the fossa, lying under the popliteal fascia, and crossing the vessels posteriorly from the lateral to the medial side. The lateral popliteal (common peroneal) nerve descends on the lateral side of the upper part of the fossa, close to the tendon of the Biceps femoris. The popliteal vessels are on the floor of the fossa, the vein being superficial to the artery and united to it by dense areolar tissue; the vein is a thick-walled vessel, and lies lateral to the artery above, and then crosses it posteriorly to gain its medial side below; sometimes it is double, the artery lying between the two veins,

FIG. 760.—A transverse section through the thigh, 4 cm. above the adductor tubercle of the femur. Four-fifths of natural size.



which are usually connected by short transverse branches. The articular branch from the obturator nerve descends upon the artery to the knee-joint. The popliteal lymph glands, six or seven in number, are imbedded in the fat; one lies beneath the popliteal fascia near the termination of the short saphenous vein, another between the popliteal artery and the back of the knee-joint, while the others are placed at the sides of the popliteal vessels.

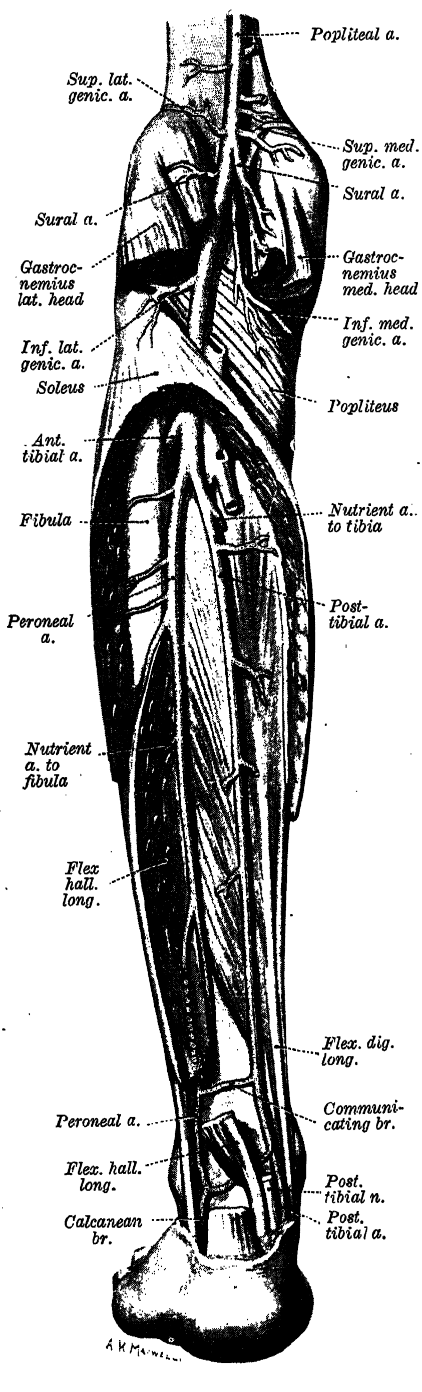
THE POPLITEAL ARTERY (figs. 760, 761)

The **popliteal artery** is the continuation of the femoral artery, and courses through the popliteal fossa. It commences at the opening in the Adductor magnus, at the junction of the middle with the lower one-third of the thigh, and extends downwards and slightly laterally to the intercondylar fossa of the femur. It then runs vertically downwards to the lower border of the Popliteus, where it divides into *anterior* and *posterior tibial arteries*.

Relations.—In *front*, from above downwards, the artery lies on the popliteal surface of the femur (separated from the vessel by some fat), the back of the knee-joint, and the fascia covering the Popliteus. *Behind*, it is overlapped by

the Semimembranosus above, and is covered by the Gastrocnemius and Plantaris below. In the middle part of its course the artery is separated from the skin and fasciæ by a quantity of fat, and is crossed from the lateral to the medial side by the medial popliteal nerve and the popliteal vein, the vein being between the nerve and the artery and closely adherent to the latter. On its *lateral side*, above, are the Biceps femoris, the medial popliteal nerve, the popliteal vein and the lateral condyle of the femur; below, the Plantaris and the lateral head of the Gastrocnemius. On its *medial* side, above, are the Semimembranosus and the medial condyle of the femur; below, the medial popliteal nerve, the popliteal vein and the medial head of the Gastrocnemius. The relations of the popliteal lymph glands to the artery are described above.

FIG. 761.—The left popliteal, posterior tibial and peroneal arteries.



Peculiarities.—Occasionally the popliteal artery divides into its terminal branches opposite the knee-joint; when this occurs the anterior tibial artery usually descends in front of the Popliteus (p. 152). The popliteal artery sometimes divides into the anterior tibial and peroneal arteries, the posterior tibial artery being wanting or rudimentary; occasionally it divides into three branches, the anterior and posterior tibial, and peroneal arteries.

Applied Anatomy.—The popliteal artery is not infrequently the seat of injury. It may be torn by direct violence, as by the passage of a cart-wheel over the knee, or by hyperextension of the knee. It may also be lacerated by fracture of the lower part of the femur, or by anteroposterior dislocation of the knee-joint. It has been torn in breaking down adhesions in cases of fibrous ankylosis of the knee, and is in danger of being wounded in performing Macewen's operation of osteotomy of the lower end of the femur for genu valgum. It is more frequently the seat of aneurysm than any other artery except the thoracic aorta. No doubt this is due in a great measure to the amount of movement to which it is subjected, and to the fact that it is supported by loose and lax tissue only, and not by muscles, as is the case with most arteries. When the knee is acutely flexed, the popliteal artery becomes bent on itself to such an extent as entirely to arrest the circulation through it.

Branches.—The branches of the popliteal artery are:

Cutaneous. Muscular { Superior. Sural.

Genicular { Superior { medial. lateral. ; Middle ; Inferior { medial. lateral.

The cutaneous branches arise either from the popliteal artery or from some of its branches; they descend between the two heads of the Gastrocnemius,

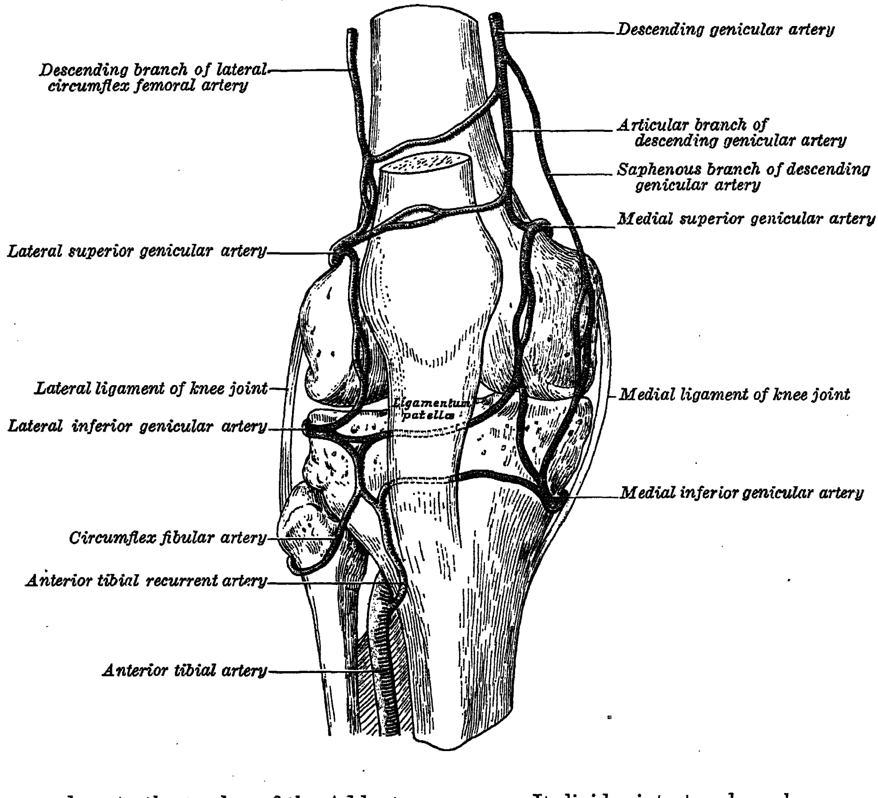
and, piercing the deep fascia, are distributed to the skin of the back of the leg ; one usually accompanies the short saphenous vein.

The **superior muscular branches**, two or three in number, arise from the upper part of the artery, and pass to the Adductor magnus and the hamstring muscles, anastomosing with the terminal part of the arteria profunda femoris.

The **sural arteries** are two large branches which arise opposite the knee-joint and are distributed to the Gastrocnemius, Soleus and Plantaris.

The **superior genicular arteries** (figs. 761, 762), two in number, arise one from each side of the popliteal artery, and wind round the femur immediately above its condyles to gain the front of the knee-joint. The *medial superior genicular artery* runs under cover of the Semimembranosus and Semitendinosus, above the medial head of the Gastrocnemius, and

FIG. 762.—The arterial anastomosis around the knee-joint.



passes deep to the tendon of the Adductor magnus. It divides into two branches, one of which supplies the Vastus medialis and anastomoses with the descending genicular (highest genicular) and medial inferior genicular arteries; the other ramifies close to the surface of the femur, and anastomoses with the lateral superior genicular artery. The size of the medial superior genicular artery varies inversely with that of the descending genicular. The *lateral superior genicular artery* passes under cover of the tendon of the Biceps femoris, and divides into a superficial and a deep branch ; the superficial branch supplies the Vastus lateralis, and anastomoses with the descending branch of the lateral circumflex femoral artery and with the lateral inferior genicular artery; the deep branch anastomoses with the medial superior genicular artery, and forms an arch across the front of the femur with the descending genicular artery.

The **middle genicular artery**, a small branch, arises from the popliteal artery opposite the back of the knee-joint; it pierces the oblique posterior ligament, and supplies the cruciate ligaments and the synovial membrane of the knee-joint.

The **inferior genicular arteries** (figs. 761, 762), two in number, arise from the popliteal artery under cover of the Gastrocnemius. The *medial inferior genicular artery* lies deep to the medial head of the Gastrocnemius and descends along the upper margin of the Popliteus, to which it gives branches; it then passes below the medial condyle of the tibia

and under cover of the medial (tibial collateral) ligament of the knee; at the anterior border of this ligament it ascends to the front and medial side of the joint, supplies the joint and the upper end of the tibia, and anastomoses with the lateral inferior and medial superior genicular arteries. The *lateral inferior genicular artery* runs laterally across the Popliteus, and then forwards above the head of the fibula to the front of the knee-joint, passing in its course under cover of the lateral head of the Gastrocnemius, the lateral (fibular collateral) ligament of the knee, and the tendon of the Biceps femoris. It divides into branches which anastomose with the medial inferior genicular, lateral superior genicular and anterior tibial recurrent arteries.

The **anastomosis around the knee-joint** (fig. 762).—Around and above the patella, and on the contiguous ends of the femur and tibia, an intricate arterial anastomosis forms a superficial and a deep network. The *superficial network* is situated between the fascia and skin round about the patella, and forms three well-defined arches; one above the patella in the loose connective tissue over the Quadriceps femoris, and two below the patella in the fat behind the ligamentum patellæ. The *deep network* lies on the lower end of the femur and upper end of the tibia around their articular surfaces, and sends numerous offsets into the interior of the joint. The vessels forming the anastomosis are the medial and lateral genicular, the descending genicular, the descending branch of the lateral circumflex femoral, the circumflex fibular, and the anterior tibial recurrent arteries.

The Anterior Tibial Artery (figs. 763, 765)

The **anterior tibial artery** is one of the two terminal branches of the popliteal artery and arises at the lower border of the Popliteus. Situated at first on the back of the leg, it passes forwards between the two heads of the Tibialis posterior and through the upper part of the interosseous membrane to the front of the leg, lying medial to the neck of the fibula. It next descends on the anterior surface of the interosseous membrane, gradually approaching the tibia: at the lower part of the leg it lies on this bone (fig. 766), and then on the front of the ankle-joint midway between the two malleoli, and is continued on the dorsum of the foot under the name of the *dorsalis pedis* artery.

Relations.—In the upper two-thirds of its extent, the anterior tibial artery rests upon the interosseous membrane of the leg; in the lower one-third, upon the front of the tibia and the ankle-joint. In the upper one-third of its course, it lies between the Tibialis anterior and Extensor digitorum longus; in the middle one-third between the Tibialis anterior and Extensor hallucis longus. At the ankle it is crossed from the lateral to the medial side by the tendon of the Extensor hallucis longus, and then lies between it and the first tendon of the Extensor digitorum longus. Its upper two-thirds are covered by the muscles which lie on each side of it, and by the deep fascia; its lower one-third, by the skin and fasciæ, and the extensor retinacula (transverse and cruciate crural ligaments).

A pair of venæ comitantes lie one on each side of the artery. The anterior tibial (deep peroneal) nerve, coursing round the lateral side of the neck of the fibula, comes into relation with the lateral side of the artery shortly after the latter reaches the front of the leg; about the middle of the leg the nerve is in front of the artery; at the lower part it is generally on its lateral side.

Peculiarities.—This vessel may be smaller than usual, or may be absent, its place being supplied by perforating branches from the posterior tibial, or by the perforating branch of the peroneal artery. The artery occasionally deviates towards the fibular side of the leg, regaining its usual position at the front of the ankle. Very occasionally it approaches the surface at the middle of the leg, and is covered merely by the skin and fasciæ below that point.

Applied Anatomy.—The anterior tibial artery is liable to be injured in fractures of the lower third of the tibia, on account of its close proximity to the bone. Ligature of the anterior tibial artery in the upper half of the leg is difficult on account of the depth of the vessel from the surface.

Branches.—The branches of the anterior tibial artery are:

Posterior tibial recurrent.	Muscular.	Anterior medial malleolar.
Anterior tibial recurrent.		Anterior lateral malleolar.

The **posterior tibial recurrent artery**—an inconstant branch—is given off from the anterior tibial artery before that vessel reaches the front of the leg. It ascends in front of the Popliteus in company with the nerve to that muscle, anastomoses with the inferior genicular branches of the popliteal artery, and gives an offset to the superior tibiofibular joint.

The **anterior tibial recurrent artery** (fig. 763) arises from the anterior tibial artery, as soon as that vessel has reached the front of the limb; it ascends in the Tibialis anterior, ramifies on the front and sides of the knee-joint, and assists in the formation of the patellar network by anastomosing with the genicular branches of the popliteal artery, and with the descending genicular artery.

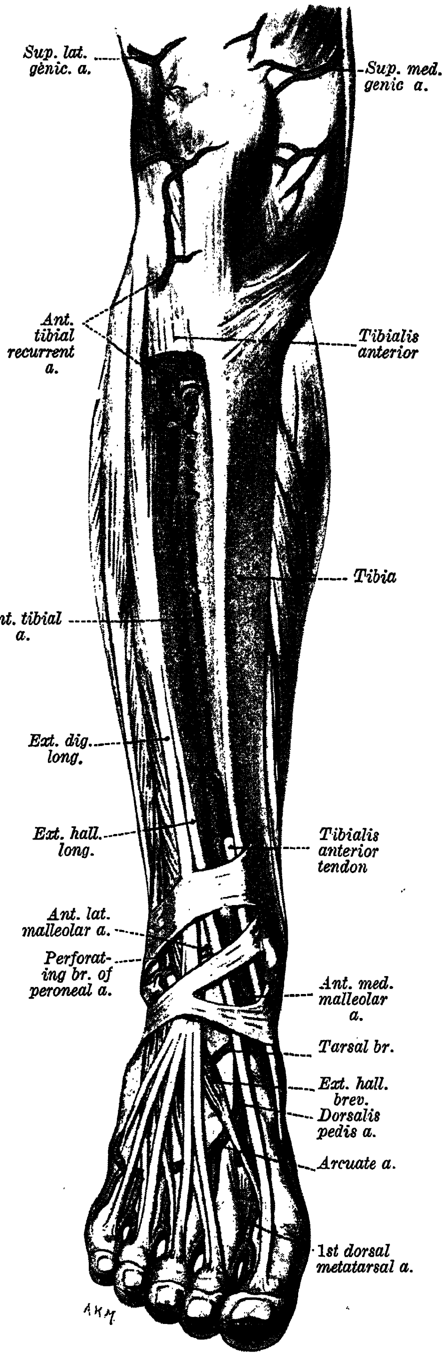
The **muscular branches** are numerous and are distributed to the muscles which lie on each side of the vessel; some pierce the deep fascia to supply the skin, others pass through the interosseous membrane of the leg, and anastomose with branches of the posterior tibial and peroneal arteries.

The **anterior medial malleolar artery** (fig. 763) arises about 5 cm. above the ankle-joint, and passes behind the tendons of the Extensor hallucis longus and Tibialis anterior, to the medial side of the ankle, where it anastomoses with branches of the posterior tibial and medial plantar arteries.

The **anterior lateral malleolar artery** (fig. 763) passes behind the tendons of the Extensor digitorum longus and Peroneus tertius; it supplies the lateral side of the ankle, and anastomoses with the perforating branch of the peroneal artery and with ascending twigs from the lateral tarsal artery.

The arteries around the ankle-joint anastomose freely with one another and form networks below the corresponding malleoli. The *medial malleolar network* is formed by the anterior medial malleolar branch of the anterior tibial artery, the medial tarsal branches of the dorsalis pedis artery, the malleolar and calcanean branches of the posterior tibial artery, and branches from the medial plantar artery. The *lateral malleolar network* is formed by the anterior lateral malleolar branch of the anterior tibial artery, the lateral tarsal branch of the dorsalis pedis artery, the perforating and the calcanean branches of the peroneal artery, and twigs from the lateral plantar artery.

FIG. 763.—The right anterior tibial and dorsalis pedis arteries.

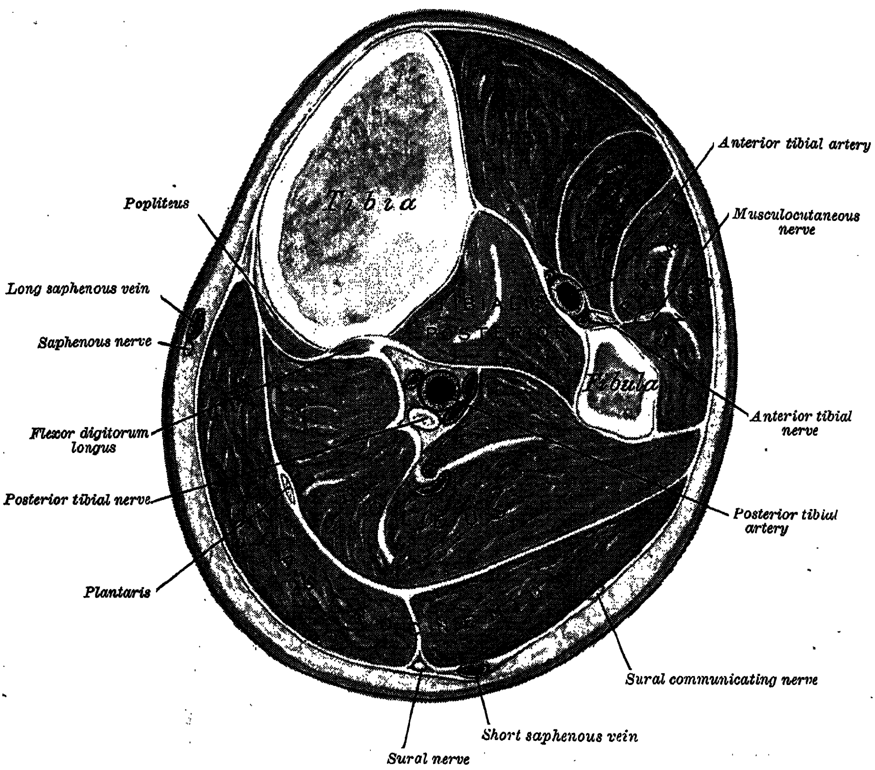


THE ARTERIA DORSALIS PEDIS (fig. 763)

The **arteria dorsalis pedis**, the continuation of the anterior tibial artery, passes forwards from the ankle-joint along the tibial side of the dorsum of the foot to the proximal part of the first intermetatarsal space, where it descends into the sole of the foot between the two heads of the first Dorsal interosseous muscle, and completes the plantar artery (fig. 768). At its junction with this artery it gives off the *first plantar metatarsal artery* (p. 802).

Relations.—The arteria dorsalis pedis is accompanied by two veins, and lies successively upon the front of the articular capsule of the ankle-joint, the talus, navicular, and intermediate cuneiform bones, and the ligaments connecting them. It is covered by the skin, fasciæ, and inferior extensor retinaculum (cruciate crural ligament), and crossed near its termination by the first tendon of the Extensor digitorum brevis. On its *tibial side* it is related to the tendon of the Extensor hallucis longus; on its *fibular side*, to the first tendon of the Extensor digitorum longus, and the medial terminal branch of the anterior tibial nerve.

FIG. 764.—A transverse section through the leg, 9 cm. below the knee-joint.



Peculiarities.—The arteria dorsalis pedis may be larger than usual, to compensate for a small lateral plantar artery; or its place may be taken by a large perforating branch of the peroneal artery. It frequently curves laterally, lying lateral to the line between the middle of the ankle and the proximal part of the first interosseous space.

Branches.—The branches of the arteria dorsalis pedis are:

Tarsal. Arcuate. First dorsal metatarsal.

The **tarsal arteries**, lateral and medial (fig. 763), arise from the arteria dorsalis pedis as the latter crosses the navicular bone. The lateral branch passes laterally under cover of the Extensor digitorum brevis; it supplies this muscle and the articulations of the tarsus, and anastomoses with branches of the arcuate, anterior lateral malleolar, and lateral plantar arteries, and with the perforating branch of the peroneal artery.

The *medial tarsal branches* are two or three small vessels which ramify on the medial border of the foot and join the medial malleolar network.

The **arcuate artery** (fig. 763) arises from the arteria dorsalis pedis opposite the medial cuneiform bone; it passes laterally over the bases of the metatarsal bones deep to the tendons of the Extensores digitorum longus et brevis, and anastomoses with the lateral tarsal and lateral plantar arteries. It gives off the *second, third* and *fourth dorsal metatarsal arteries*, which run forwards upon the corresponding Dorsal interosseous muscles; in the clefts between the toes each divides into two dorsal digital branches for the sides of the

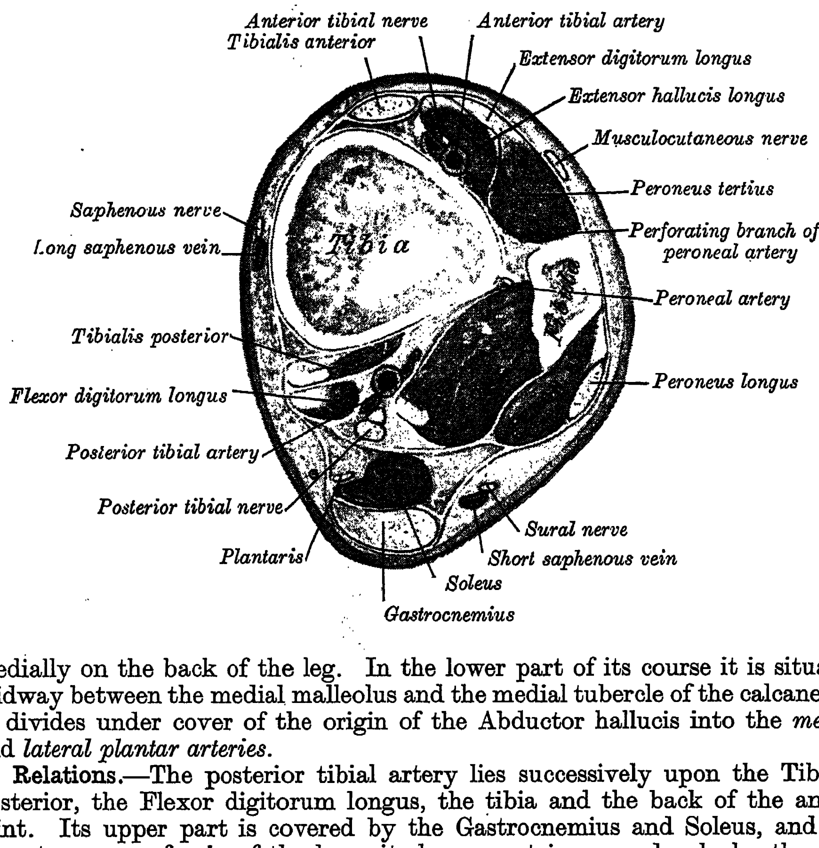
adjoining toes. At the proximal parts of the interosseous spaces the dorsal metatarsal arteries receive the posterior perforating branches from the plantar arch, and at the distal parts of the spaces they are joined by the anterior perforating branches from the plantar metatarsal arteries. The fourth dorsal metatarsal artery gives off a branch which supplies the lateral side of the fifth toe.

The **first dorsal metatarsal artery** arises from the dorsalis pedis artery just before it descends into the sole; it runs forward on the first Dorsal interosseous muscle, and at the cleft between the first and second toes divides into two branches, one of which passes beneath the tendon of the Extensor hallucis longus, and is distributed to the medial border of the great toe; the other bifurcates to supply the adjoining sides of the great and second toes.

The Posterior Tibial Artery (figs. 761, 765)

The **posterior tibial artery** begins at the lower border of the Popliteus, opposite the interval between the tibia and fibula, and passes downwards and

Fig. 765.—A transverse section through the leg, 6 cm. above the tip of the medial malleolus.



medially on the back of the leg. In the lower part of its course it is situated midway between the medial malleolus and the medial tubercle of the calcaneum. It divides under cover of the origin of the Abductor hallucis into the *medial* and *lateral plantar arteries.*

Relations.—The posterior tibial artery lies successively upon the Tibialis posterior, the Flexor digitorum longus, the tibia and the back of the ankle-joint. Its upper part is covered by the Gastrocnemius and Soleus, and the deep transverse fascia of the leg; its lower part is covered only by the skin and fascia, and runs parallel with, and about 2·5 cm. in front of, the medial border of the tendo calcaneus; its terminal part is deep to the flexor retinaculum (laciniate ligament) and the Abductor hallucis. It is accompanied by two veins, and by the posterior tibial nerve, which lies at first on its medial side, but soon crosses it posteriorly, and is, in the greater part of its course, on its lateral side.

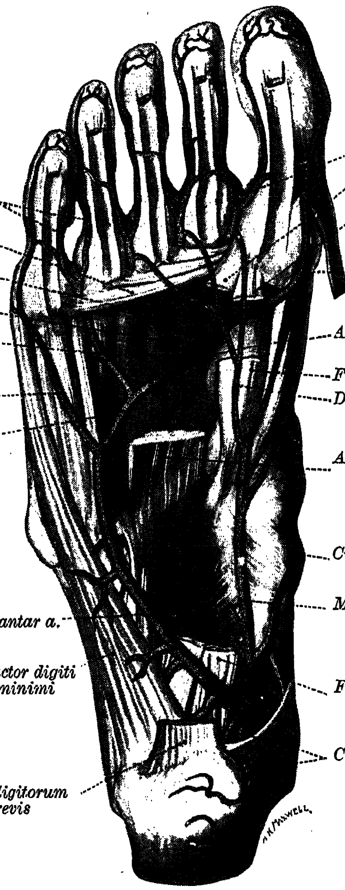
The structures which pass from the back of the leg to the sole of the foot under cover of the flexor retinaculum are arranged in the following order from the medial to the lateral side; first, the tendons of the Tibialis posterior and Flexor digitorum longus lying in the same groove behind the malleolus, the former being the more medial; then the posterior tibial artery, with a vein on each

side of it; lateral to the posterior tibial vessels is the posterior tibial nerve, and about 1·25 cm. nearer the heel, the tendon of the Flexor hallucis longus (fig. 761).

Peculiarities.—The posterior tibial artery may be small or absent, its place being supplied by a large peroneal artery, which either joins the small posterior tibial artery, or continues alone to the sole of the foot.

Applied Anatomy.—Ligature of the posterior tibial artery may be required in cases of wound of the sole of the foot, attended with great hæmorrhage; the vessel should then be tied at the ankle. In cases of wound of the posterior tibial, it will be necessary to enlarge

Fig. 766.—The arteries of the sole of the right foot.



the opening so as to expose the vessel at the wounded point, excepting where the vessel is injured by a punctured wound from the front of the leg.

Branches.—The branches of the posterior tibial artery are:

1. Circumflex fibular.
2. Peroneal.
3. Nutrient.
4. Muscular.
5. Communicating.
6. Malleolar.
7. Calcanean.
8. Medial plantar.
9. Lateral plantar.

1. The **circumflex fibular artery,** sometimes a branch of the anterior tibial artery, passes laterally, round the neck of the fibula, through the Soleus, and anastomoses with the lateral inferior genicular artery.

2. The **peroneal artery** (fig. 761) arises from the posterior tibial, about 2·5 cm. below the lower border of the Popliteus. It passes obliquely towards the fibula, and descends along the medial crest of that bone, contained in a fibrous canal between the Tibialis posterior and the Flexor hallucis longus,

or in the substance of the latter muscle. It then runs behind the inferior tibiofibular joint, and divides into calcanean branches, which ramify on the lateral and posterior surfaces of the calcaneum. Its *upper* part is covered by the Soleus and the deep transverse fascia of the leg; its *lower* part, by the Flexor hallucis longus.

Peculiarities.—The peroneal artery may spring from the posterior tibial artery at a higher level than usual, or may even be a branch of the popliteal artery; sometimes it arises 7 or 8 cm. below the inferior border of the Popliteus. It is more frequently increased than diminished in size; and then it either joins and reinforces the posterior tibial artery, or takes the place of that artery in the lower part of the leg and foot. When the peroneal artery is smaller than usual, an additional branch from the posterior tibial artery takes its place; and a branch from the anterior tibial artery compensates for the diminished perforating artery.

Fig. 767.—The plantar arteries. Superficial dissection.

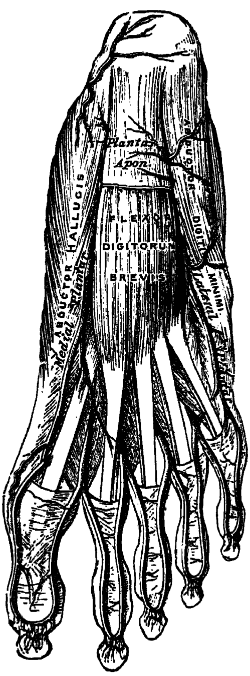
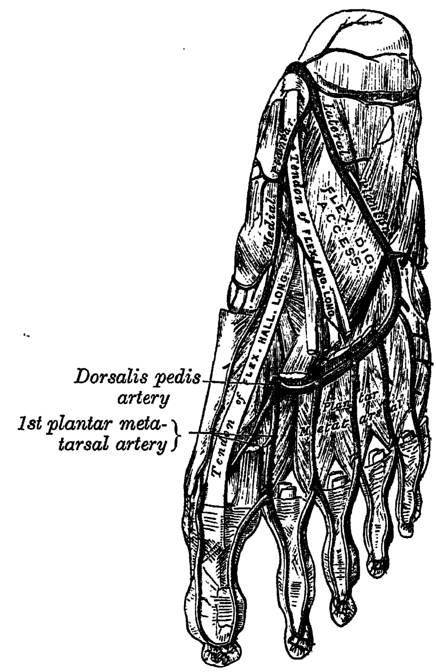


Fig. 768.—The plantar arteries. Deep dissection.



The peroneal artery gives off the following branches:

Muscular branches are supplied to the Soleus, Tibialis posterior, Flexor hallucis longus and Peronei.

A nutrient artery supplies the fibula, and is directed downwards.

A perforating branch pierces the interosseous membrane of the leg, about 5 cm. above the lateral malleolus, and reaches the front of the leg, where it anastomoses with the anterior lateral malleolar artery; it then descends in front of the inferior tibiofibular joint, gives branches to the tarsus, and anastomoses with the lateral tarsal artery. The perforating branch is sometimes enlarged, and may take the place of the dorsalis pedis artery.

A communicating branch arises from the peroneal artery about 5 cm. above the lower end of the tibia, and joins the communicating branch of the posterior tibial artery.

The **calcanean** or terminal branches of the peroneal artery pass to the lateral side of the heel, and communicate with the anterior lateral malleolar artery and, on the back of the heel, with the calcanean branches of the posterior tibial artery.

3. The **nutrient artery** of the tibia arises from the posterior tibial artery near its origin, and, after supplying a few minute muscular branches, runs downwards to enter the nutrient canal in the bone, at a point immediately below the soleal line (popliteal line).

4. **Muscular branches** are distributed to the Soleus and to the deep muscles on the back of the leg.

5. The **communicating branch** runs transversely across the back of the tibia about 5 cm. above its lower end, deep to the Flexor hallucis longus, and joins the communicating branch of the peroneal artery.

6. The **malleolar branch** is a small vessel which winds round the tibial malleolus and ends in the medial malleolar network.

7. The **calcanean branches** arise from the posterior tibial just before its division; they pierce the flexor retinaculum (laciniate ligament) and are distributed to the fat and skin behind the tendo calcaneus and about the heel, and to the muscles on the tibial side of the sole, anastomosing with the peroneal and medial malleolar arteries, and, on the back of the heel, with the calcanean branches of the peroneal artery.

8. The **medial plantar artery** (figs. 767, 768), the smaller terminal branch of the posterior tibial artery, passes forwards along the medial side of the foot in company with the medial plantar nerve, which lies to its lateral side. It is at first deep to the Abductor hallucis, and then runs forwards between it and the Flexor digitorum brevis, both of which it supplies. At the base of the first metatarsal bone, where it is much diminished in size, it passes along the medial border of the first toe and anastomoses with the first dorsal metatarsal artery. It supplies three small superficial digital branches which accompany the digital branches of the medial plantar nerve and join the first, second and third plantar metatarsal arteries.

9. The **lateral plantar artery** (fig. 768), the larger of the terminal branches of the posterior tibial artery, passes at first obliquely laterally and forwards to the base of the fifth metatarsal bone in company with the lateral plantar nerve, which lies on its medial side. It then turns medially with the deep branch of the nerve, to the interval between the bases of the first and second metatarsal bones, where it unites with the dorsalis pedis artery, thus completing the *plantar arch*. As this artery passes laterally, it is first placed between the calcaneum and Abductor hallucis, and then between the Flexor digitorum brevis and Flexor digitorum accessorius; as it runs forwards to the base of the fifth metatarsal bone it lies between the Flexor digitorum brevis and Abductor digiti minimi, and is covered by the plantar aponeurosis, superficial fascia and skin.

Branches.—The lateral plantar artery gives off muscular, superficial and anastomotic branches. The *muscular branches* supply the adjoining muscles; the *superficial branches* emerge along the line of the lateral intermuscular septum and supply the skin and subcutaneous tissue of the lateral part of the sole; the *anastomotic branches* run to the lateral border of the foot, where they anastomose with branches of the lateral tarsal and arcuate arteries. In addition, the lateral plantar artery sometimes gives off a *calcanean* branch, which pierces the origin of the abductor hallucis to supply the skin of the heel.

The **plantar arch** is deeply situated and extends from the base of the fifth metatarsal bone to the proximal part of the first interosseous space. It is convex forwards, lies below the bases of the second, third and fourth metatarsal bones and the corresponding Interossei, and above the oblique part of the Adductor hallucis.

Branches.—The plantar arch gives off three perforating and four plantar metatarsal branches, and distributes numerous twigs to the skin, fasciæ and muscles in the sole.

The three **perforating branches** ascend through the proximal parts of the second, third and fourth interosseous spaces, between the heads of the Dorsal interosseous muscles, and anastomose with the dorsal metatarsal arteries.

The four **plantar metatarsal arteries** (fig. 768) run forwards between the metatarsal bones and in contact with the Interossei. Each divides into a pair of plantar digital arteries, which supply the adjacent sides of the toes. Near their points of division each plantar metatarsal artery sends upwards an *anterior perforating branch* to join the corresponding dorsal metatarsal artery. The first plantar metatarsal artery springs from the junction between the lateral plantar and the dorsalis pedis arteries (p. 798), and sends a digital branch to the medial side of the first toe. The digital branch for the lateral side of the fifth toe arises from the lateral plantar artery near the base of the fifth metatarsal bone.

Applied Anatomy.—Wounds of the plantar arch are always serious, on account of the depth of the vessel and the important structures which must be interfered with in an attempt to ligature it. They must be treated on similar lines to those of wounds of the palmar arches (p. 756). Pressure locally, combined with elevation of the limb, may in some cases be sufficient to arrest the bleeding, but if this fails, an attempt should be made to find the bleeding point and ligature it. Should this prove unsuccessful, it may be necessary to ligature the femoral artery below the origin of the arteria profunda femoris, as ligature of the anterior and posterior tibial arteries may not be sufficient to control the hæmorrhage, and in the circumstances it is safer and quicker to tie the femoral artery.

THE VEINS

The veins convey the blood from the different parts of the body to the heart. They receive the blood from the capillaries, and unite with one another to form larger vessels which, in their passage towards the heart, increase in size as they receive tributaries, or join other veins. The veins are larger and more numerous than the arteries; hence, the capacity of the veins is greater than that of the arteries; the capacity of the pulmonary veins, however, exceeds that of the pulmonary arteries only to a slight extent. The veins are cylindrical like the arteries; their walls, however, are thin and they collapse when the vessels are empty, and the uniformity of their surfaces may be interrupted at intervals by slight constrictions, caused by the presence of valves in their interior (p. 666). They communicate very freely with one another, especially in certain regions of the body. Thus, between the venous sinuses of the cranium, and between the veins of the neck, where obstruction would be attended by imminent danger to the cerebral circulation, numerous anastomoses are found. Free communications also exist between the veins of the vertebral canal, and between the veins composing the various venous plexuses in the abdomen and pelvis.

The veins consist of two sets, viz. *pulmonary* and *systemic.*

The **pulmonary veins**, unlike other veins, contain oxygenated blood, which they return from the lungs to the left atrium of the heart.

The **systemic venous channels** return the venous blood from the body generally to the right atrium of the heart, and are subdivided into three sets, viz. superficial and deep veins, and venous sinuses.

The **superficial veins** lie in the superficial fascia, immediately under the skin; they return the blood from these structures, and eventually join the deep veins. In their mode of origin and termination the superficial veins are subject to considerable variation.

The **deep veins** accompany the arteries, and are usually enclosed in the same sheaths with those vessels. With the smaller arteries—as the radial, ulnar, brachial, tibial, peroneal—they exist generally in pairs, one lying on each side of the artery, and are called *venæ comitantes.* The larger arteries—such as the axillary, subclavian, popliteal and femoral—have usually only one accompanying vein. In certain regions, however, the deep veins do not accompany the arteries; for instance, the cerebral veins, the veins of the skull and vertebral canal, the hepatic veins in the liver, and the larger veins returning blood from the bones.

Venous sinuses are found only in the interior of the skull, and are canals between the two layers of the dura mater. Their walls are devoid of muscular tissue and consist of endothelium only.

The **portal vein**, an appendage to the systemic venous system, is confined to the abdominal cavity, and conveys the venous blood from the spleen and the viscera of digestion to the liver, where it breaks up into a network of capillary like vessels (sinusoids), from which the blood is drained by the hepatic veins to the inferior vena cava.

THE PULMONARY VEINS

The **pulmonary veins** return the oxygenated blood from the lungs to the left atrium of the heart. They are four in number, two from each lung, and are destitute of valves. They commence in the capillary network on the walls of the alveoli of the lungs, and, joining together, form one vessel from each lobule of the lung. These vessels, uniting successively, form a single trunk from each lobe, three from the right lung and two from the left. The vein from the middle lobe of the right lung generally unites with that from the upper lobe, so that ultimately two veins, a superior and an inferior, leave each lung; they perforate the fibrous layer of the pericardium and open separately into the upper and posterior part of the left atrium (fig. 676). Occasionally the three veins on the right side remain separate. Sometimes the two left pulmonary veins unite to form a single trunk before entering the heart.

In the root of the lung, the superior pulmonary vein lies in front of and a little below the pulmonary artery; the inferior is situated at the lowest part of the hilum of the lung and on a plane posterior to that of the superior vein. The bronchus is behind the pulmonary artery.

On the right side the upper pulmonary vein passes behind the superior vena cava, and the lower behind the right atrium.

On the left side both pulmonary veins pass in front of the descending thoracic aorta.

Within the pericardium, their anterior surfaces are invested by the serous layer of this membrane.

THE SYSTEMIC VEINS

The **systemic veins** may be arranged into three groups: 1. The veins of the heart. 2. The veins of the upper limbs, head, neck and thorax, all of which end in the superior vena cava. 3. The veins of the lower limbs, abdomen and pelvis, all of which end in the inferior vena cava.

THE VEINS OF THE HEART (fig. 769)

The **coronary sinus.**—Most of the veins of the heart open into the coronary sinus. This is a wide venous channel about 2 or 3 cm. long situated in the posterior part of the atrioventricular groove (coronary sulcus) of the heart (fig. 769), between the left atrium and left ventricle. It is completely surrounded by cardiac muscle, and some fibres from the left atrium may be carried over its posterior aspect. It ends in the right atrium between the opening of the inferior vena cava and the atrioventricular orifice, its aperture being guarded by a semilunar valve, named the *valve of the coronary sinus* (fig. 678).

Its tributaries are the great, small, and middle cardiac veins, the posterior vein of the left ventricle, and the oblique vein of the left atrium, all of which, except the last, are provided with valves at their orifices.

1. The **great cardiac vein** (fig. 769) begins at the apex of the heart and ascends in the anterior interventricular sulcus to reach the atrioventricular groove. It then curves to the left in this groove, and, reaching the back of the heart, opens into the left extremity of the coronary sinus. It receives tributaries from the left atrium and from both ventricles, including the *left marginal vein*, which ascends along the left margin of the heart and is of considerable size.

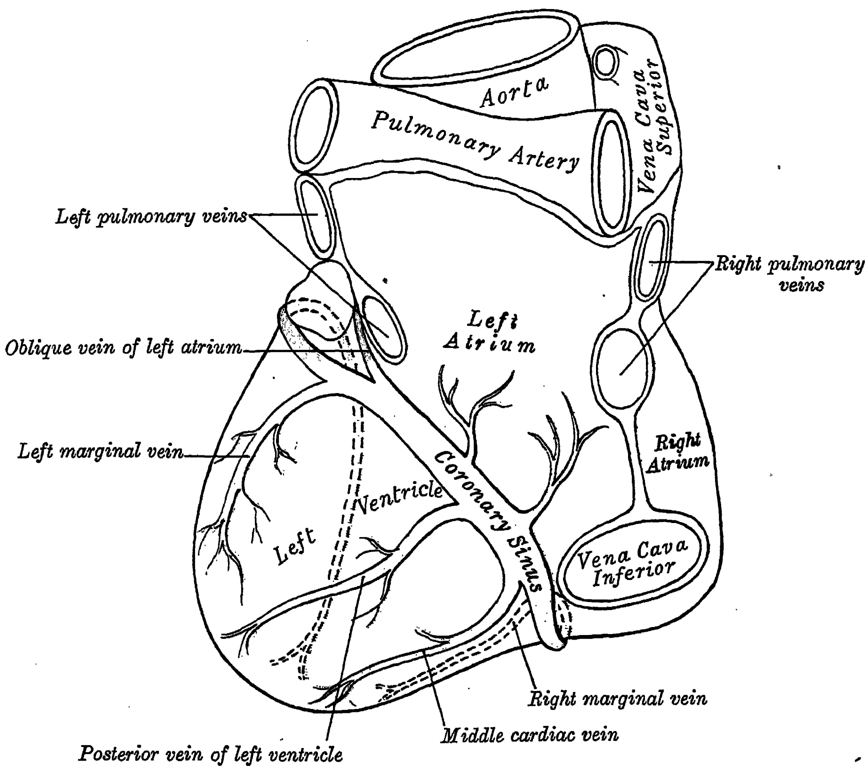
2. The **small cardiac vein** (fig. 769) runs in the atrioventricular groove between the right atrium and ventricle posteriorly, and opens into the right extremity of the coronary sinus. It receives blood from the back of the right atrium and ventricle; the *right marginal vein* ascends along the right margin of the heart and joins the small cardiac vein in the atrioventricular groove, or opens directly into the right atrium.

3. The **middle cardiac vein** (fig. 769) begins at the apex of the heart, runs backwards in the inferior interventricular groove, and ends in the coronary sinus near its right extremity.

4. The **posterior vein of the left ventricle** (fig. 769) runs on the diaphragmatic surface of the left ventricle a little to the left of the middle cardiac vein ; it usually opens into the coronary sinus, but may end in the great cardiac vein.

5. The **oblique vein of the left atrium** (fig. 769) is a small vessel which descends obliquely on the back of the left atrium and ends in the coronary sinus near its

FIG. 769.—A scheme showing the veins of the heart.



left extremity ; it is continuous above with the *ligament of the left vena cava* (p. 669), and the two structures are remnants of the left duct of Cuvier (p. 158).

The following cardiac veins do not end in the coronary sinus : (1) the **anterior cardiac veins,** comprising three or four small vessels which collect blood from the front of the right ventricle and open into the right atrium ; the right marginal vein frequently opens into the right atrium, and is therefore sometimes regarded as belonging to this group ; (2) the **venæ cordis minimæ,** comprising a number of minute veins, which lie in the muscular wall of the heart and open directly into its cavities, most of them into the atria, but a few into the ventricles.

THE VEINS OF THE HEAD AND NECK

The venous channels of the head and neck may be subdivided into : 1. The veins of the exterior of the head and face. 2. The veins of the neck. 3. The diploic veins, the veins of the brain and the venous sinuses of the dura mater.

The Veins of the Exterior of the Head and Face (fig. 770)

Supratrochlear.	Maxillary.
Supra-orbital.	Posterior facial.
Anterior facial.	Posterior auricular.
Superficial temporal.	Occipital.

The **supratrochlear vein** (frontal vein) begins on the forehead in a venous network which communicates with the frontal tributaries of the superficial temporal vein. Veins converge from the network to form a single trunk, which descends on the forehead near the median plane parallel with the vein of the opposite side. At the root of the nose the two supratrochlear veins are joined by a transverse branch which is called the *nasal arch,* and receives small veins from the dorsum of the nose. The supratrochlear veins then diverge, and at the medial angle of the orbit, each joins with the *supra-orbital vein* to form the *anterior facial vein.* Occasionally the supratrochlear veins unite in a single trunk, which divides at the root of the nose into the two anterior facial veins.

The **supra-orbital vein** begins near the zygomatic process of the frontal bone, where it communicates with the superficial and middle temporal veins. It courses medially along the upper margin of the orbital opening under cover of the Orbicularis oculi, and, at the medial angle of the eye, pierces this muscle and unites with the supratrochlear vein to form the *anterior facial vein.* It sends a branch through the supra-orbital notch into the orbital cavity to join the superior ophthalmic vein; as this branch traverses the supra-orbital notch it is joined by the frontal diploic vein.

The **anterior facial vein,** formed by the junction of the supratrochlear and supra-orbital veins, runs obliquely downwards on the side of the root of the nose, to the level of the lower margin of the orbital opening. It then runs downwards and backwards behind the facial (external maxillary) artery, but follows a less tortuous course. It passes under cover of the Zygomaticus major, Risorius and Platysma, descends along the anterior border and then on the surface of the Masseter, crosses over the body of the mandible, and runs obliquely backwards, deep to the Platysma and superficial to the submandibular (submaxillary) gland, Digastric and Stylohyoid. A little below and in front of the angle of the mandible, it unites with the anterior branch of the posterior facial vein to form the *common facial vein,* which descends across the loop of the lingual artery, the hypoglossal nerve and the external and internal carotid arteries, and enters the internal jugular vein near the greater cornu of the hyoid bone. From near the termination of the common facial vein a branch of considerable size often runs down the anterior border of the Sternomastoid to join the lower part of the anterior jugular vein.

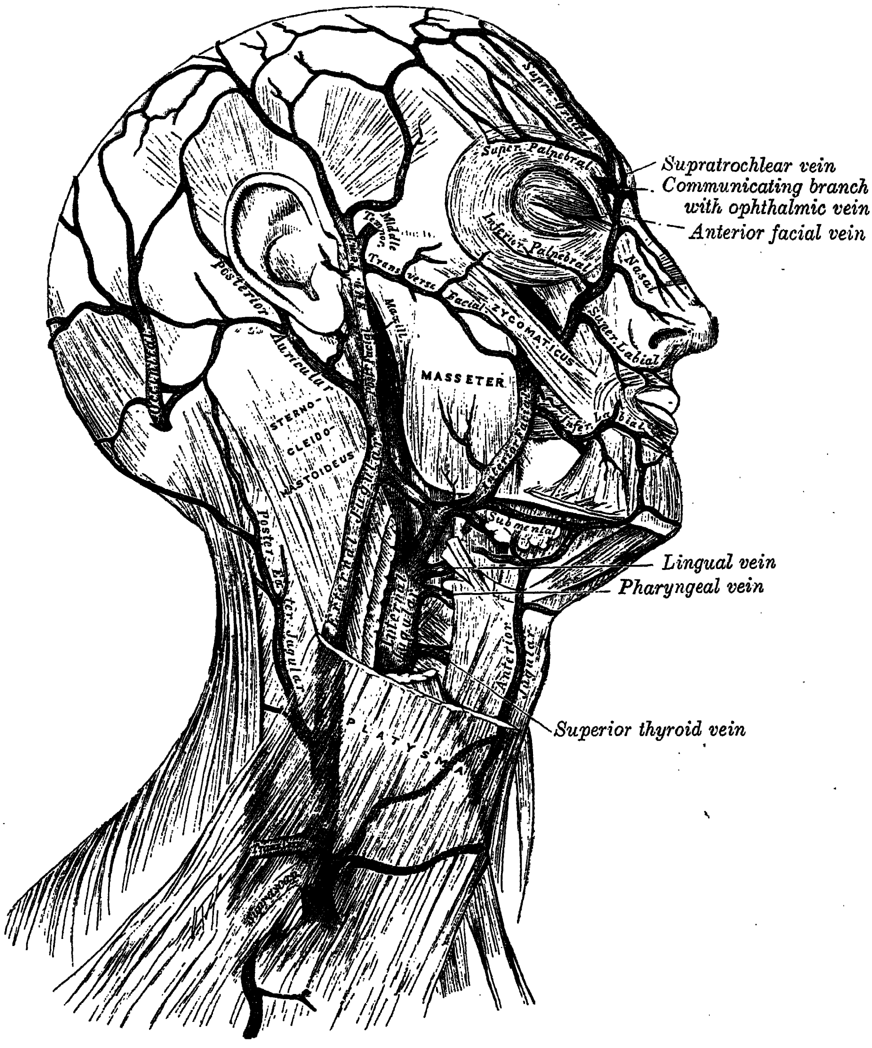
Tributaries.—The anterior facial vein receives the veins of the ala nasi, and communicates with the superior ophthalmic vein. Through this communication and the communication of the superior ophthalmic vein with the supra-orbital vein, an anastomosis is established between the anterior facial vein and the cavernous sinus. At a lower level the anterior facial vein receives a large branch, named the *deep facial vein,* from the pterygoid venous plexus. It is also joined by the inferior palpebral, the superior and inferior labial, the buccinator, the parotid and the masseteric veins. Below the mandible it receives the submental, external palatine and submandibular (submaxillary) veins. The common facial vein may be joined by the vena comitans of the hypoglossal nerve, and often receives the pharyngeal and superior thyroid veins.

Applied Anatomy.—The anterior facial vein is not so flaccid as most superficial veins, and, in consequence of this, shows less tendency to collapse when divided. It has, moreover, no valves. It communicates freely with the intracranial circulation, not only at its commencement and by the supra-orbital veins, which are connected with the ophthalmic vein, a tributary of the cavernous sinus, but also by the deep facial vein, which communicates through the pterygoid plexus, with the cavernous sinus (p. 818). These facts have an important bearing upon the surgery of some diseases; any phlegmonous inflammation of the face following an infected wound is liable to set up thrombosis in the anterior facial

vein, and detached portions of the clot may give rise to purulent foci in other parts of the body. These thrombi may extend upwards into the cranial sinuses, and so induce a fatal issue ; this has been known to follow in the case of ordinary carbuncle of the face. The position of the vein must be borne in mind when incisions are made for the relief of suppuration about the mandible.

The **superficial temporal vein** (fig. 770) begins on the side and vertex of the skull in a network which communicates with the corresponding vein of the opposite side, and with the supratrochlear, supra-orbital, posterior auricular

FIG. 770.—The veins of the right side of the head and neck.



and occipital veins. From this network, anterior and posterior tributaries arise, and unite above the zygomatic arch to form the superficial temporal vein, which is joined in this situation by the *middle temporal vein*. It then crosses the posterior root of the zygomatic arch, enters the substance of the parotid gland, and unites with the maxillary vein to form the posterior facial vein.

Tributaries.—The superficial temporal vein receives some veins from the parotid gland, articular veins from the mandibular joint, anterior auricular veins from the auricle, and the *transverse facial* from the side of the face. The middle temporal vein, after receiving the *orbital vein*, which is formed by some lateral palpebral branches, passes backwards between the layers of the temporal fascia and joins the superficial temporal vein.

The **pterygoid plexus** is of considerable size, and is situated partly between the Temporal and Lateral pterygoid muscles, and partly between the two Pterygoids. It receives the sphenopalatine, deep temporal, pterygoid, masseteric, buccal, dental, and greater palatine veins, and a branch or branches from the inferior ophthalmic vein. The pterygoid plexus anastomoses with the anterior facial vein, through the deep facial vein; it is also connected with the cavernous sinus by veins which pass through the emissary sphenoidal foramen (foramen Vesalii), foramen ovale and foramen lacerum.

The **maxillary vein** (internal maxillary vein) is a short trunk which accompanies the first part of the corresponding artery and is formed by a confluence of the veins of the pterygoid plexus. It passes backwards between the spheno-mandibular ligament and the neck of the mandible, and unites with the superficial temporal vein to form the posterior facial vein.

The **posterior facial vein,** formed by the union of the superficial temporal and maxillary veins, descends in the substance of the parotid gland, superficial to the external carotid artery but deep to the facial nerve. It divides into two branches, an anterior which passes forwards and unites with the anterior facial vein to form the common facial vein, and a posterior which is joined by the posterior auricular vein to form the external jugular vein.

The **posterior auricular vein** (fig. 770) begins on the posterior part of the side of the head, in a network which communicates with the tributaries of the occipital and superficial temporal veins. It descends behind the auricle, and joins the posterior division of the posterior facial vein in or just below the parotid gland to form the external jugular vein. It receives the stylomastoid vein and some tributaries from the cranial surface of the auricle.

The **occipital vein** (fig. 770) begins in a venous network at the posterior part of the skull. It pierces the cranial attachment of the Trapezius, dips into the suboccipital triangle and joins the deep cervical and vertebral veins. Occasionally it follows the course of the occipital artery and ends in the internal jugular vein; sometimes it joins the posterior auricular vein and, through it, opens into the external jugular vein. The parietal emissary vein connects it with the superior sagittal sinus, and the mastoid emissary vein with the transverse sinus. The occipital diploic vein sometimes joins it.

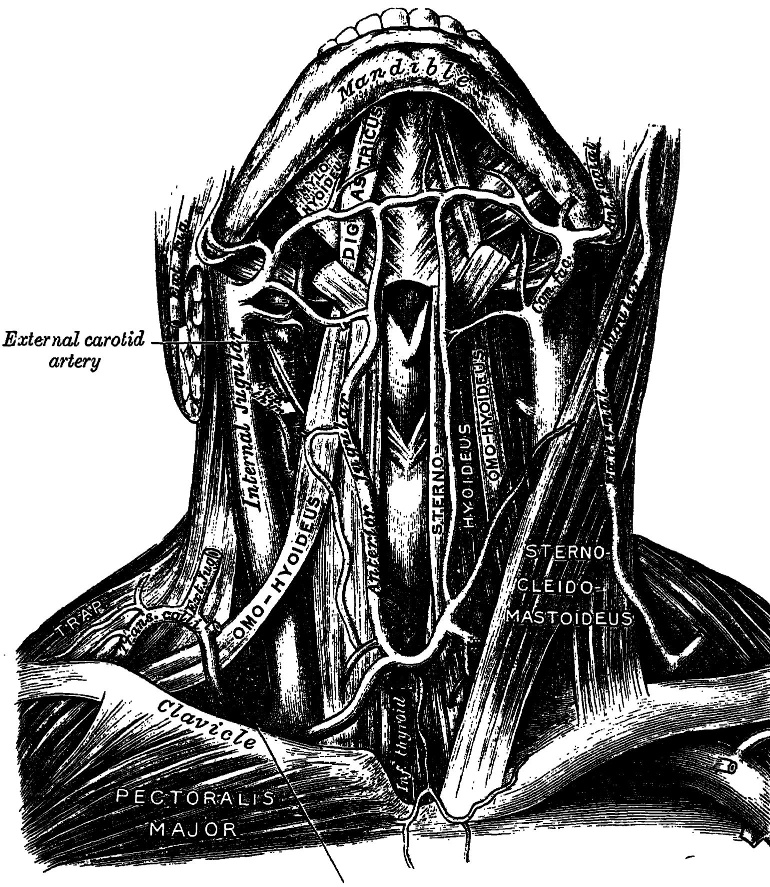
The Veins of the Neck (figs. 770, 772)

External jugular.	Anterior jugular.
Posterior external jugular.	Internal jugular.
Vertebral.	

The **external jugular vein** (fig. 770) receives the greater part of the blood from the exterior of the cranium and from the deep parts of the face, and is formed by the union of the posterior division of the posterior facial vein with the posterior auricular vein. It begins on a level with the angle of the mandible, just below the parotid gland, or, sometimes, in its substance, and runs down the neck, where its course is represented by a line drawn from the angle of the mandible to the middle of the clavicle. It crosses the Sternomastoid obliquely, and in the subclavian triangle perforates the deep fascia to end in the subclavian vein, lateral to, or in front of, the Scalenus anterior; the wall of the vein is adherent to the circumference of the opening in the deep fascia. It is covered by the Platysma, superficial fascia, and skin, and separated from the Sternomastoid by the investing layer of the deep cervical fascia; it crosses the anterior cutaneous nerve of the neck, and its upper half runs parallel with the great auricular nerve, which ascends behind it. The external jugular vein varies in size, bearing an inverse proportion to the other veins of the neck; it is occasionally double. It is provided with two pairs of valves, a lower pair at its entrance into the subclavian vein, an upper about 4 cm. above the clavicle. The portion of the vein between the two sets of valves is often dilated, and is sometimes termed the *sinus*. These valves do not prevent regurgitation of the blood, or the passage of injection from below upwards.

Tributaries.—The external jugular vein receives the posterior external jugular, and, near its termination, the transverse cervical, suprascapular transverse scapular) and anterior jugular veins; in the parotid gland it is frequently joined by a branch from the internal jugular vein. The occipital vein occasionally opens into it.

FIG. 771.—The veins of the neck. Anterior aspect. (After Spalteholz.)



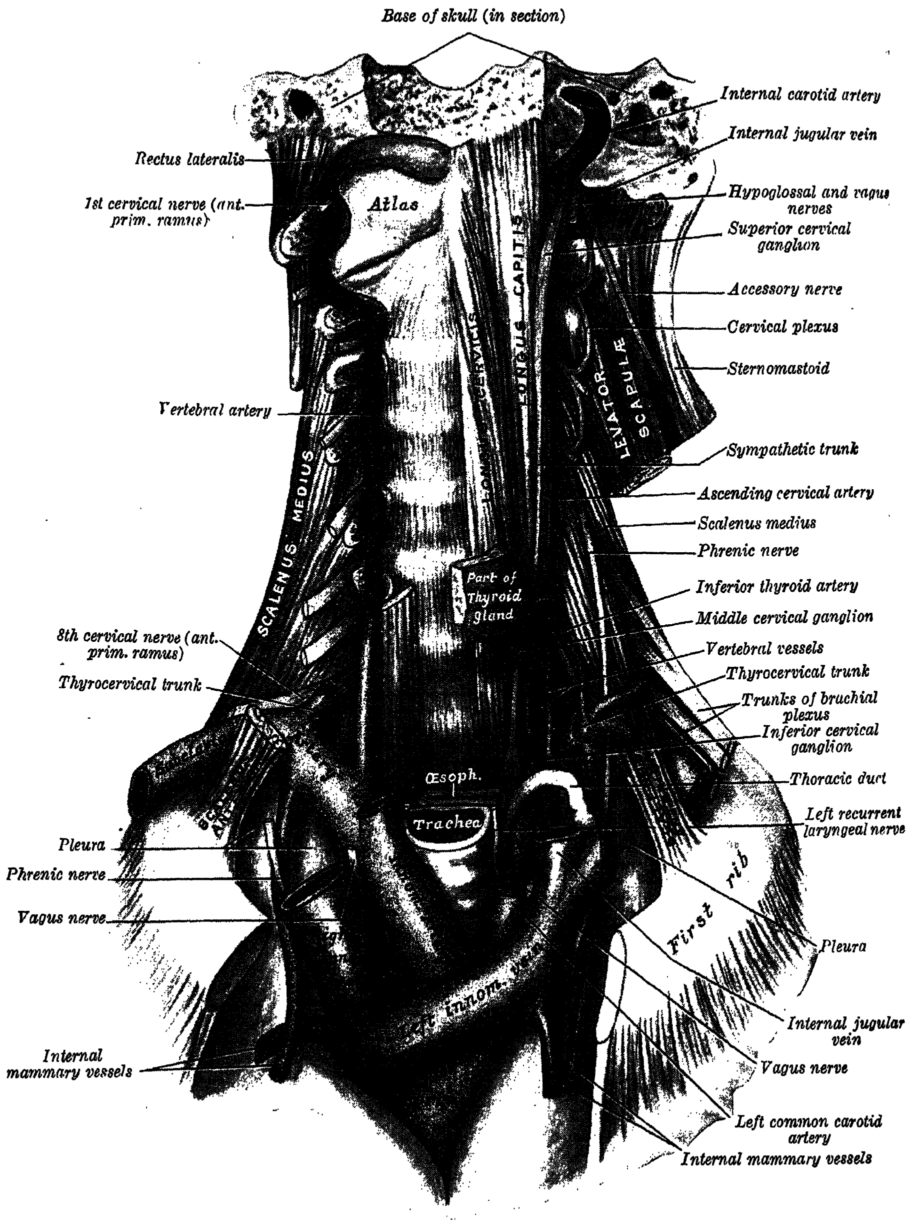
Applied Anatomy.—Venesection used formerly to be performed on the external jugular vein, but is now probably never resorted to. When the vein is cut there is some risk of air being drawn into it.

The **posterior external jugular vein** begins in the occipital region and returns the blood from the skin and superficial muscles in the upper and posterior part of the neck. It opens into the middle part of the external jugular vein.

The **anterior jugular vein** (figs. 770, 771) is devoid of valves and begins near the hyoid bone by the confluence of several superficial veins from the submandibular region. It descends between the anterior median line and the anterior border of the Sternomastoid; at the lower part of the neck it turns laterally under cover of that muscle, but superficial to the depressors of the hyoid bone, and opens into the termination of the external jugular vein, or into the subclavian vein. Its size varies considerably, and usually bears an inverse proportion to that of the external jugular vein. It communicates with the internal jugular vein and receives as tributaries some laryngeal veins, and occasionally a small thyroid vein. There are usually two anterior jugular veins, a right and a left; just above the sternum they are united by a large transverse

trunk, termed the *jugular arch,* which receives tributaries from the inferior thyroid veins. The anterior jugular veins may be replaced by a single trunk which descends in the anterior median line of the neck.

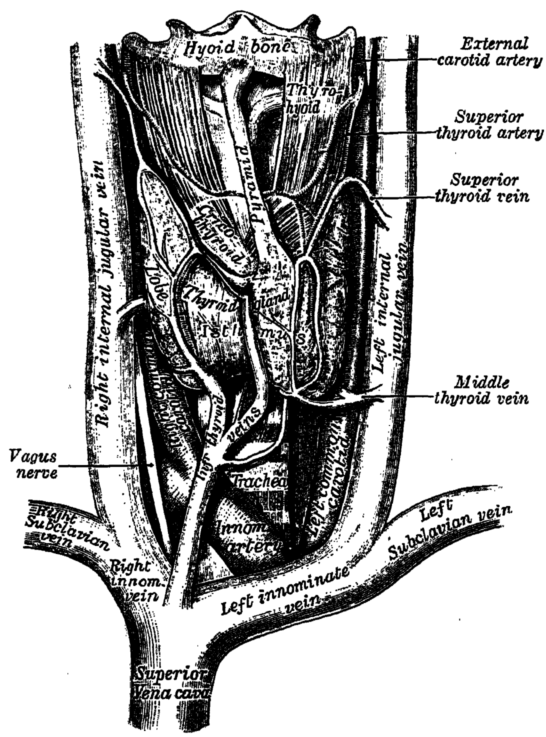
FIG. 772.—A drawing of a dissection of the prevertebral and upper thoracic regions showing the vessels, etc., near the root of the neck, the cervical course of the vertebral artery, and the structures which lie posterior to the internal jugular vein.



The **internal jugular vein** (fig. 771) collects the blood from the brain, from the superficial parts of the face, and from the neck. It begins at the base of the skull in the posterior compartment of the jugular foramen, where it is directly continuous with the sigmoid sinus. At its origin it is somewhat dilated; this dilatation, which is called the *superior bulb,* lies below the posterior part of the floor of the tympanic cavity. The vein runs downwards through the neck

within the carotid sheath (fig. 584), and, behind the sternal end of the clavicle, unites with the subclavian vein to form the innominate vein. The internal jugular vein is dilated near its termination to form what is known as the *inferior bulb*; directly above this bulb the vein contains a pair of valves. *Posteriorly* the internal jugular vein rests, from above downwards, on the Rectus capitis lateralis, the transverse process of the atlas, the Levator scapulæ, the Scalenus medius and the cervical plexus; then on the Scalenus anterior, the phrenic nerve, the thyrocervical trunk, the vertebral vein and the first part of the subclavian artery; on the left side it passes in front of the thoracic duct (fig. 772). *Medially* the vein is related to the internal and common carotid arteries, and to the vagus nerve, the last lying between the vein and the arteries but on a plane posterior to them. *Superficially* the vein is overlapped by the upper part, and covered by the lower part, of the Sternomastoid, and is crossed by the posterior belly of the Digastric and the superior belly of the Omohyoid. Above the Digastric it is covered by the parotid gland and the styloid process, and is crossed by the accessory nerve and the posterior auricular and occipital arteries. Between the Digastric and the Omohyoid the sternomastoid arteries and the nervus descendens cervicalis cross the vein, but the nerve often passes between it and the common carotid artery. Below the Omohyoid it is covered by the infrahyoid muscles, in addition to the Sternomastoid, and is crossed superficial to the infrahyoid muscles by the anterior jugular vein. The deep cervical lymph glands lie along the course of the vein, mainly on its superficial aspect. At the root of the neck the right internal jugular vein is placed at a little distance from the common carotid artery, while the left vein usually overlaps the artery. At the base of the skull the internal carotid artery is in front of the internal jugular vein, and is separated from it by the last four cranial nerves.

Fig. 773.—The veins of the thyroid gland.



Tributaries.—The internal jugular vein receives the inferior petrosal sinus, the common facial, lingual, pharyngeal, superior and middle thyroid veins, and sometimes the occipital vein. In the upper part of the neck it may communicate with the external jugular vein. The thoracic duct opens into the angle of union of the left subclavian and internal jugular veins, and the right lymphatic duct into the angle of union of the right subclavian and internal jugular veins.

The **inferior petrosal sinus** leaves the skull through the anterior part of the jugular foramen and, crossing either lateral or medial to the ninth, tenth and eleventh cranial nerves, joins the superior bulb of the internal jugular vein.

The **lingual veins** begin on the dorsum, sides, and under surface of the tongue, and, passing backwards along the course of the lingual artery, end in the internal jugular vein near the greater cornu of the hyoid bone. The **vena comitans hypoglossi**—a vein of considerable size—begins below the tip of the tongue, and may join the lingual veins; generally, however, it passes backwards superficial to the Hyoglossus, and opens into the common facial vein.

The **pharyngeal veins** begin in the *pharyngeal plexus* on the outer surface of the pharynx, and, after receiving some meningeal veins and the vein of the pterygoid canal, end in the internal jugular vein. They occasionally open into the facial, the lingual, or the superior thyroid vein.

The **superior thyroid vein** (fig. 773) begins in the substance and on the surface of the thyroid gland, by tributaries corresponding with the branches of the superior thyroid artery. It accompanies this artery, receives the superior laryngeal and cricothyroid veins, and ends in the internal jugular or in the common facial vein.

The **middle thyroid vein** (fig. 773) collects the blood from the lower part of the thyroid gland, and receives some veins from the larynx and trachea. It crosses in front of the common carotid artery, and ends in the lower part of the internal jugular vein under cover of the superior belly of the Omohyoid.

The inferior thyroid veins are described on p. 826.

The **common facial** and **occipital veins** have been described (pp. 806, 808).

Applied Anatomy.—The internal jugular vein requires ligature in cases of septic thrombosis of the sigmoid sinus, secondary to suppurative otitis media, in order to prevent septic emboli being carried into the general circulation. This operation has been performed in many cases, with the most satisfactory results. These cases are always extremely grave, for there is a danger of portions of the thrombus or clot being detached and causing septic embolism in the lungs. When the thrombosis involves the superior bulb of the internal jugular vein, the glossopharyngeal, vagus and accessory nerves may be paralysed. The hypoglossal nerve is sometimes paralysed by extension of the thrombus to the veins of the anterior condylar canal.

The internal jugular vein is also important surgically, because it is surrounded by a number of deep cervical lymph glands; and when these are enlarged in tuberculous or malignant disease, they are apt to adhere to the vessel, rendering their removal difficult and often dangerous.

Cardiac pulsation is often demonstrable in the internal jugular vein at the root of the neck. There are no valves in the innominate veins or superior vena cava; in consequence, the systole of the right atrium causes a wave to pass up these vessels, and when the conditions are favourable this wave appears as a somewhat feeble flicker over the internal jugular vein at the root of the neck, quite distinct from, and just preceding, the more forcible impulse transmitted from the underlying common carotid artery and due to the ventricular systole. This atrial systolic venous impulse is much increased in conditions in which the right atrium is abnormally distended with blood or is hypertrophied, as is often the case in disease of the mitral valve. In the Adams-Stokes' syndrome it is this pulsation which gives evidence of the fact that the atria are beating faster—often two or three times faster—than the ventricles.

The **vertebral vein** is formed in the suboccipital triangle, from numerous small tributaries which spring from the internal vertebral plexuses and issue from the vertebral canal above the posterior arch of the atlas. They unite with small veins from the deep muscles at the upper part of the back of the neck, and form a vessel which enters the foramen in the transverse process of the atlas, and descends, forming a dense plexus around the vertebral artery, in the canal formed by the foramina transversaria of the cervical vertebræ. This plexus ends in the vertebral vein, which emerges from the foramen transversarium of the sixth cervical vertebra, and runs downwards, at first anterior and then anterolateral to the vertebral artery, to open into the upper and posterior part of the innominate vein, the opening being guarded by a pair of valves. In its course the vertebral vein descends behind the internal jugular vein and in front of the first part of the subclavian artery (fig. 772). A small vein usually descends from the plexus around the vertebral artery, passes through the foramen transversarium of the seventh cervical vertebra, and curves forwards between the subclavian artery and the cervical pleura to join the innominate vein.

Tributaries.—The vertebral vein communicates with the sigmoid sinus of the skull by a vein which passes through the posterior condylar canal, when that canal exists. It receives branches from the occipital vein, from the prevertebral muscles, and from the internal and external vertebral plexuses. It is joined by the anterior vertebral and the deep cervical veins; close to its termination it sometimes receives the first intercostal vein.

The **anterior vertebral vein** commences in a plexus around the transverse processes of the upper cervical vertebræ, descends in company with the ascending

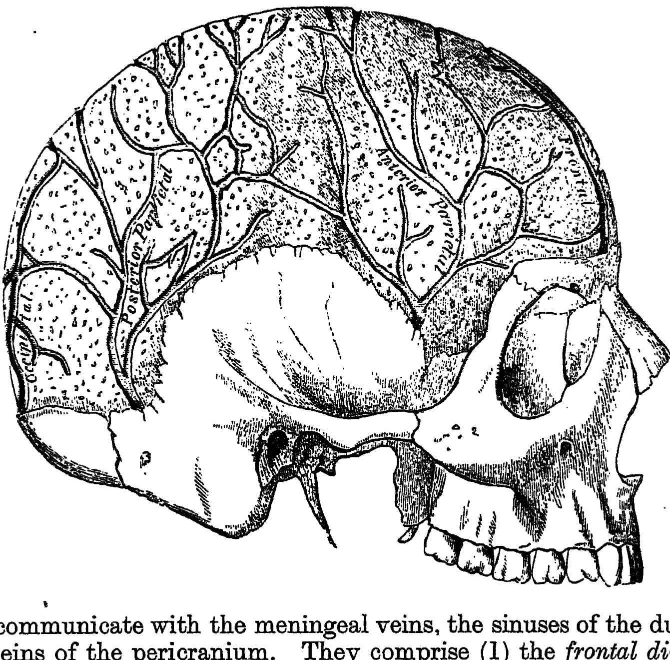
cervical artery between the Scalenus anterior and Longus capitis, and opens into the terminal part of the vertebral vein.

The **deep cervical vein** accompanies its artery between the Semispinales capitis et cervicis. It begins in the suboccipital region by communicating branches from the occipital vein and by small veins from the deep muscles at the back of the neck. It receives tributaries from the plexuses around the spines of the cervical vertebræ, and passes forwards between the transverse process of the seventh cervical vertebra and the neck of the first rib to end in the lower part of the vertebral vein.

The Diploic Veins (fig. 774)

The **diploic veins** occupy channels in the diploë of the cranial bones and are devoid of valves. They are large, and exhibit pouch-like dilatations at irregular intervals; their walls are thin, and formed of endothelium supported by a layer of elastic tissue.

Fig. 774.—The veins of the diploë. Displayed by the removal of the outer table of the skull.



They communicate with the meningeal veins, the sinuses of the dura mater, and the veins of the pericranium. They comprise (1) the *frontal diploic vein,* which emerges from the bone at the supra-orbital foramen and opens into the supra-orbital vein; (2) the *anterior parietal diploic vein,* which is confined chiefly to the frontal bone and pierces the greater wing of the sphenoid bone to end in the sphenoparietal sinus or in the anterior deep temporal vein; (3) the *posterior parietal diploic vein,* which is situated in the parietal bone; it descends to the posterior inferior angle of the parietal bone and joins the transverse sinus through an aperture placed at that angle or through the mastoid foramen; and (4) the *occipital diploic vein,* the largest of the four, which is confined to the occipital bone and opens into the occipital vein, or into the transverse sinus near the confluence of the sinuses. In addition, numerous small diploic veins pierce the inner table close to the margins of the superior sagittal sinus and terminate in the venous lacunæ (p. 815).

The Veins of the Brain

The veins of the brain possess no valves, and their walls, owing to the absence of muscular tissue, are extremely thin. They pierce the arachnoid mater and the inner or meningeal layer of the dura mater, and open into the cranial venous sinuses. They comprise two sets, cerebral and cerebellar.

The **cerebral veins** are divisible into external and internal groups, according as they drain the outer surfaces or the inner parts of the hemispheres.

The **external cerebral veins** are the superior, middle and inferior.

The *superior cerebral veins*, eight to twelve in number on each hemisphere, drain the superolateral and medial surfaces of the hemispheres, and are mainly lodged in the sulci between the gyri, but some run across the gyri. They ascend to the superomedial border of the hemisphere, where they receive small veins from the medial surface of the hemisphere, and open into the superior sagittal sinus ; the anterior veins run nearly at right angles to the sinus ; the posterior and larger veins are directed obliquely forwards, and thus open into the sinus in a direction opposed to the current of the blood contained within it.

The *superficial middle cerebral vein* begins on the lateral surface of the hemisphere, and, following the posterior ramus and the stem of the lateral sulcus (lateral cerebral fissure), ends in the cavernous sinus. The *superior anastomotic vein* runs backwards and upwards between the middle cerebral vein and the superior sagittal sinus, and thus a communication is established between the superior sagittal and cavernous sinuses. A second vein, named the *inferior anastomotic vein*, courses over the temporal lobe, and connects the middle cerebral vein to the transverse sinus.

The *inferior cerebral veins* are of small size, and drain the under surface of the hemisphere. Those on the orbital surface of the frontal lobe join the superior cerebral veins, and through these open into the superior sagittal sinus ; those of the temporal lobe anastomose with the basal and middle cerebral veins, and join the cavernous, superior petrosal and transverse sinuses.

The *basal vein* begins at the anterior perforated substance by the union of (*a*) a small *anterior cerebral vein*, which accompanies the anterior cerebral artery, (*b*) the *deep middle cerebral vein*, which receives the tributaries from the insula and neighbouring gyri, and runs in the floor of the lateral cerebral sulcus, and (*c*) the *striate veins*, which pass through the anterior perforated substance. The basal vein passes backwards round the cerebral peduncle and ends in the great cerebral vein ; it receives tributaries from the interpeduncular fossa, the inferior horn of the lateral ventricle, the hippocampal gyrus and the mid-brain.

The **internal cerebral veins**, two in number, drain the deep parts of the hemisphere ; each is formed near the interventricular foramen by the union of the *thalamostriate* (terminal) and *choroid veins*. They run backwards parallel with each other, between the layers of the tela chorioidea of the third ventricle, and below the splenium of the corpus callosum, where they unite to form the *great cerebral vein*.

The *thalamostriate vein* (terminal vein) runs in the groove between the caudate nucleus and the thalamus, receives numerous veins from both of these structures, and unites behind the anterior column of the fornix with the choroid vein, to form the internal cerebral vein. The *choroid vein* runs along the whole length of the choroid plexus, and receives veins from the hippocampus, the fornix, and the corpus callosum.

The **great cerebral vein**, formed by the union of the two internal cerebral veins, is a short median trunk which curves sharply upwards around the splenium of the corpus callosum and opens into the anterior extremity of the straight sinus, after receiving the right and left basal veins.

The **cerebellar veins** are placed on the surface of the cerebellum, and consist of two sets, superior and inferior. Some of the *superior cerebellar veins* pass forwards and medially, across the superior vermis, to end in the straight sinus and in the internal cerebral veins ; others run laterally to the transverse and superior petrosal sinuses. The *inferior cerebellar veins*, of large size, end in the sigmoid, superior petrosal and occipital sinuses.

The Venous Sinuses of the Dura Mater (figs. 775 to 779)

The sinuses of the dura mater are venous channels which drain the blood from the brain ; they are situated between the two layers of the dura mater and are lined by endothelium continuous with that which lines the veins ; they contain no valves, and their walls are devoid of muscular tissue. They may be

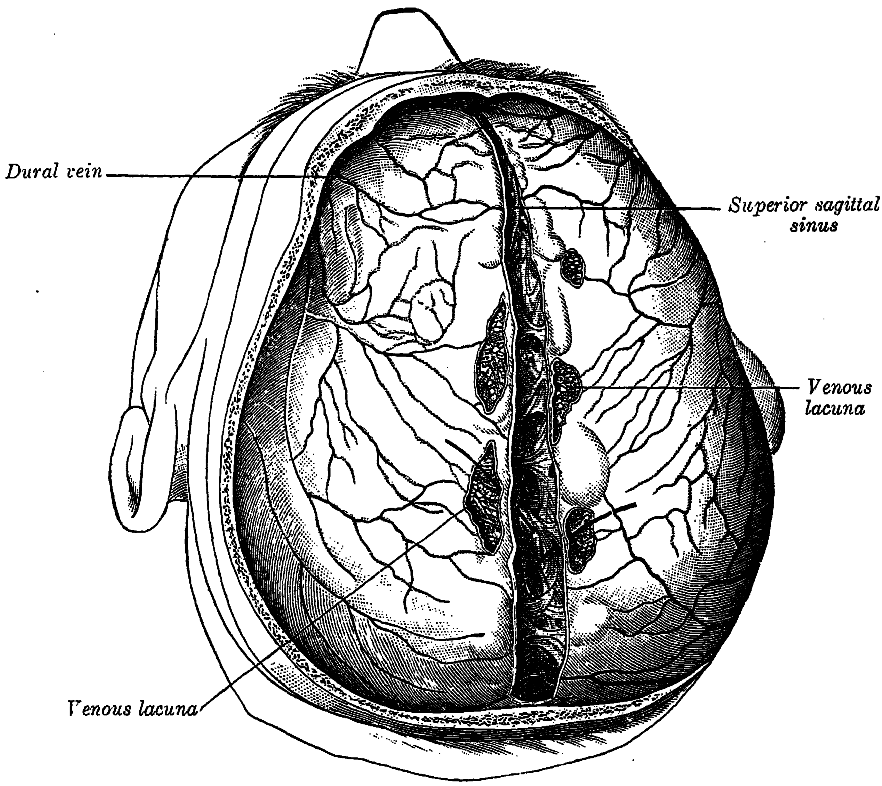
divided into two groups: (1) a posterosuperior, at the upper and posterior parts of the skull, and (2) an antero-inferior, at the base of the skull.

1. The posterosuperior group of venous sinuses:

Superior sagittal.	Two transverse.
Inferior sagittal.	Two sigmoid.
Straight.	Occipital.

The **superior sagittal sinus** (figs. 775, 776) occupies the attached, convex margin of the falx cerebri. It commences in front of the crista galli, where it receives a vein from the nasal cavity on the rare occasions when the foramen

FIG. 775.—The superior sagittal sinus laid open after the removal of the skull-cap. The fibrous bands which cross the sinus and the venous lacunæ are clearly seen; from two of the lacunæ bristles are passed into the sinus. (Poirier and Charpy.)



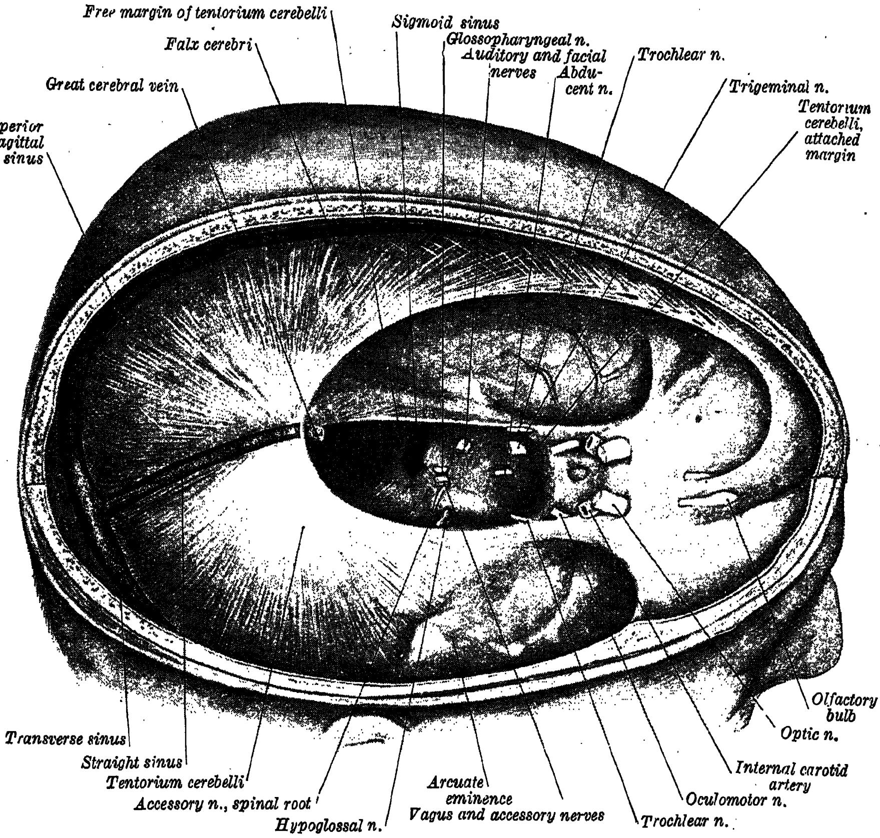
cæcum is patent; it runs backwards, grooving the inner surface of the frontal bone, the adjacent margins of the two parietal bones, and the squamous part of the occipital bone; near the internal occipital protuberance it deviates to one or other side (usually the right), and is continued as the corresponding transverse sinus. It is triangular in cross-section, and gradually increases in size as it passes backwards. Its inner surface presents the openings of the superior cerebral veins, projecting arachnoid granulations, and numerous fibrous bands which cross the inferior angle of the sinus; the sinus also communicates through small openings with irregularly-shaped *venous lacunæ* (lacunæ laterales), which are situated in the dura mater near the sinus. There are usually three lacunæ laterales on each side of the sinus: a small frontal, a large parietal, and an occipital, which is intermediate in size between the other two (Sargent *). Many fine fibrous bands cross the lacunæ, and numerous arachnoid granulations project into them from below. The superior sagittal sinus receives the superior

* Percy Sargent, *Journal of Anatomy and Physiology*, vol. xlv.

cerebral veins, and, near the posterior extremity of the sagittal suture, veins from the pericranium which pass through the parietal foramina ; the venous lacunæ receive the diploic and meningeal veins.

The *confluence of the sinuses* (fig. 777), is the term applied to the dilated posterior extremity of the superior sagittal sinus. It is lodged on one side (generally the right) of the internal occipital protuberance, and from it the transverse sinus of the same side is derived. It receives also the blood from the occipital sinus, and is connected by a channel with the commencement of the opposite transverse sinus.

FIG. 776.—The dura mater and its processes. Exposed by removing part of the right half of the skull, and the brain.



According to le Gros Clark * the lacunæ laterales should not be described as single well-defined cavities, but rather as a complicated meshwork of veins into which the diploic veins and the superior terminations of the meningeal veins open. He states that the superior cerebral veins never open into the lacunæ, but pass beneath them and open directly into the superior sagittal sinus.

Applied Anatomy.—The communications which take place between the superior sagittal sinus and the veins of the nose, scalp, and diploë, cause it to be at times the seat of infective thrombosis from suppurative processes in these parts.

The **inferior sagittal sinus** (fig. 776) is contained in the posterior one-half or two-third of the free margin of the falx cerebri. It increases in size as it passes backwards, and ends in the straight sinus. It receives several veins from the falx cerebri, and occasionally a few from the medial surfaces of the hemispheres.

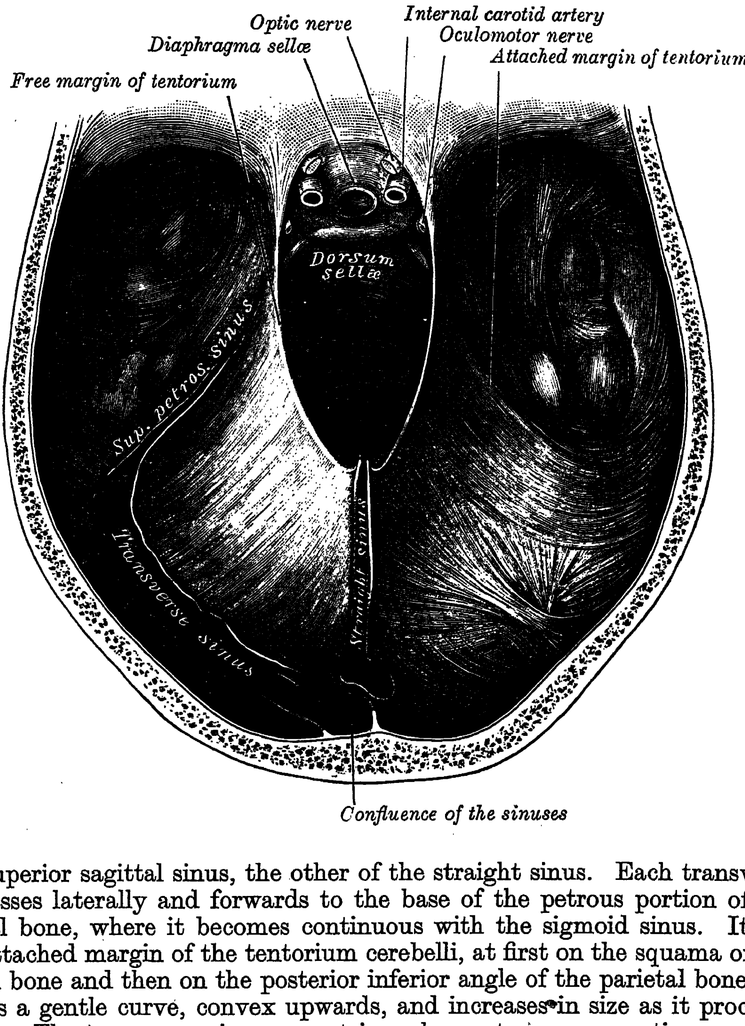
The **straight sinus** (figs. 776, 777) is situated in the line of junction of the falx cerebri with the tentorium cerebelli. It is triangular in cross-section and

* W. E. le Gros Clark, *Journal of Anatomy*, vol. lv.

is traversed by a few transverse bands. It runs backwards and downwards from the end of the inferior sagittal sinus to the transverse sinus of the side opposite to that into which the superior sagittal sinus is prolonged. Its terminal part communicates by a cross branch with the confluence of the sinuses. Besides the inferior sagittal sinus, it receives some of the superior cerebellar veins, and, at its commencement, the great cerebral vein, the site of the opening of this vein being marked by a dilatation.

The **transverse sinuses** (fig. 777, 778) are of large size, and begin at the internal occipital protuberance ; one, generally the right, being the direct continuation

Fig. 777.—The tentorium cerebelli. Superior aspect.

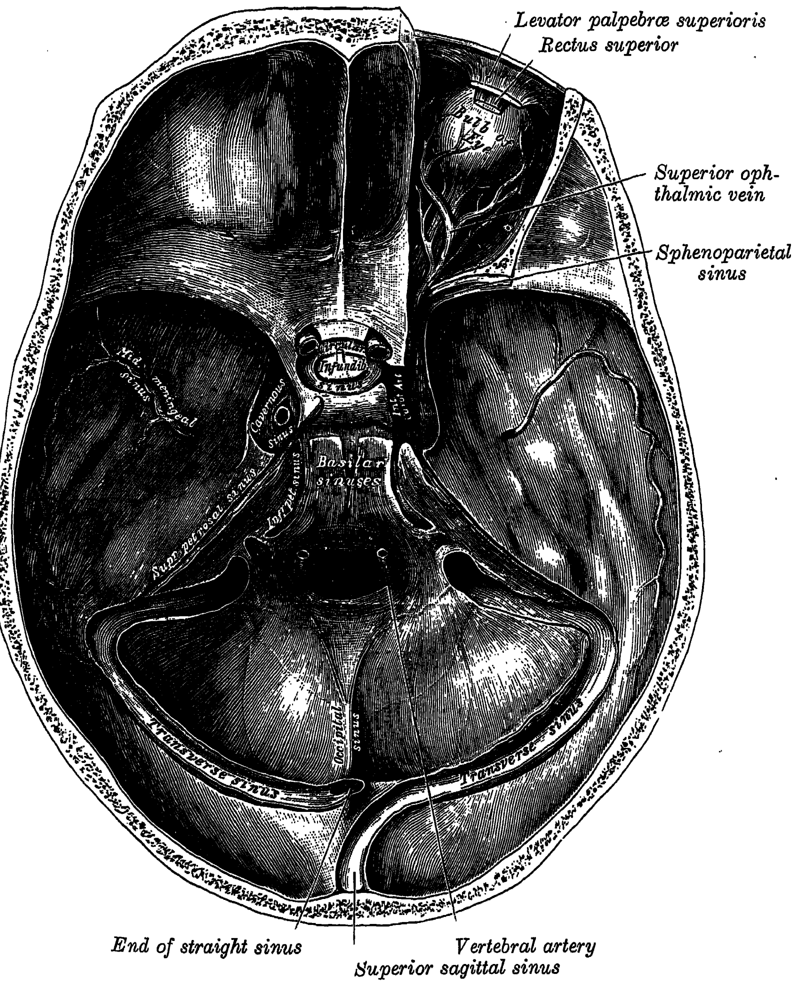


of the superior sagittal sinus, the other of the straight sinus. Each transverse sinus passes laterally and forwards to the base of the petrous portion of the temporal bone, where it becomes continuous with the sigmoid sinus. It lies in the attached margin of the tentorium cerebelli, at first on the squama of the occipital bone and then on the posterior inferior angle of the parietal bone. It describes a gentle curve, convex upwards, and increases in size as it proceeds forwards. The transverse sinuses are triangular on transverse section, and are frequently of unequal size, that formed by the superior sagittal sinus being the larger. At the point where they become continuous with the sigmoid sinuses, they are joined by the superior petrosal sinuses ; and in their course they receive some inferior cerebral, inferior cerebellar, and diploic veins, and the inferior anastomotic vein (p. 814). The *petrosquamous sinus*, when present, runs backwards along the junction of the squama and petrous portion of the temporal bone, and opens into the transverse sinus. Anteriorly, it communicates with the external jugular vein through a postglenoid (p. 296) or a squamosal foramen (p. 295).

The **sigmoid sinuses** (fig. 778) are directly continuous with the transverse sinuses at the point where the latter leave the tentorium cerebelli. Each

sigmoid sinus curves downwards and medially in a deep groove on the mastoid part of the temporal bone, crosses the jugular process of the occipital bone, and then turns forwards to become continuous with the superior bulb of the internal jugular vein in the posterior part of the jugular foramen. Anteriorly a very thin plate of bone separates the upper part of the sigmoid sinus from the tympanic antrum and mastoid air-cells. Each sinus communicates with the veins of the pericranium by means of the mastoid and condylar emissary veins.

FIG. 778.—The sinuses at the base of the skull.



The **occipital sinus** (fig. 778), the smallest of the cranial sinuses, is situated in the attached margin of the falx cerebelli, and is generally unpaired, but two may be present. It commences near the margin of the foramen magnum in several small venous channels, one of which joins the terminal part of the sigmoid sinus ; it communicates with the internal vertebral plexuses, and ends in the confluence of the sinuses.

2. The antero-inferior group of venous sinuses :

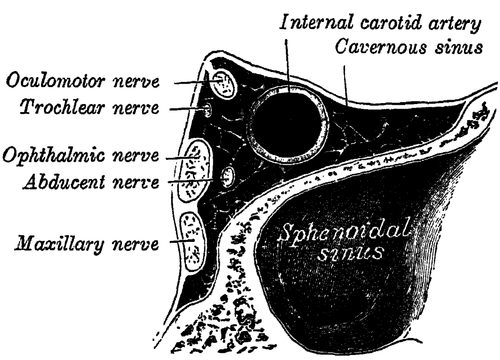
Cavernous.	Superior petrosal.	Basilar.
Sphenoparietal.	Inferior petrosal.	Middle meningeal.
Intercavernous.		

The **cavernous sinuses** (figs. 778, 779) are placed on the sides of the body of the sphenoid bone, and are so named because they present a spongy structure, due to their being traversed by numerous interlacing filaments. Each extends

from the superior orbital fissure in front, to the apex of the petrous part of the temporal bone behind, and has an average length of 2 cm. and a width of 1 cm. The internal carotid artery, surrounded by a plexus of sympathetic filaments, passes forwards through the sinus; the abducent nerve, in this part of its course, lies inferolateral to the artery; the oculomotor and trochlear nerves, and the ophthalmic and maxillary divisions of the trigeminal nerve (fig. 779) are placed in the lateral wall of the sinus. These structures are separated from the blood in the sinus by the lining membrane of the sinus. The sphenoidal sinus and the hypophysis cerebri are medial to the cavernous sinus. The cavum trigeminale (p. 1024) is closely related to the lower and posterior part of its lateral wall, and extends backwards beyond the sinus, enclosing the trigeminal (semilunar) ganglion. The uncus forms an additional relation of the lateral wall.

The tributaries of the cavernous sinus are the superior ophthalmic vein, a branch from the inferior ophthalmic vein, the superficial middle cerebral vein, some inferior cerebral veins, and the sphenoparietal sinus; the central vein of the retina and the anterior trunk of the middle meningeal sinus sometimes open into it. The cavernous sinus communicates with the transverse sinus through the superior petrosal sinus; with the internal jugular vein through the inferior petrosal sinus and a plexus of veins on the internal carotid artery; with the pterygoid venous plexus by veins which pass through the emissary sphenoidal foramen (Vesalii), foramen ovale, and foramen lacerum; and with the anterior facial vein through the superior ophthalmic vein. The two sinuses also communicate with each other by means of the anterior and posterior intercavernous sinuses and the network of basilar sinuses.

Fig. 779.—An oblique section through the left cavernous sinus.



The **sphenoparietal sinuses** (fig. 778) run on the under surfaces of the lesser wings of the sphenoid bone, near their posterior edges. Each sinus receives some small veins from the adjacent part of the dura mater and may receive one of the middle meningeal sinuses; it opens into the anterior part of the cavernous sinus.

Applied Anatomy.—An arteriovenous communication may be established between the cavernous sinus and the internal carotid artery, giving rise to a pulsating tumour in the orbit. Such communication may be the result of a bullet wound, a stab, or a blow or fall sufficiently severe to cause a fracture of the base of the skull in this situation. Ligature of the internal or common carotid artery has been performed in these cases with considerable success.

It is now well known that caries in the upper parts of the nasal cavities and suppuration in certain of the accessory sinuses of the nose are frequently responsible for septic thrombosis of the cavernous sinuses, in exactly the same way as thrombosis of the sigmoid sinus is due to septic disease in the mastoid process. Many deaths from meningitis, hitherto unaccounted for, are in reality due to the spread of an infection from the ethmoidal or sphenoidal sinuses to the cavernous sinuses, and thence to the meninges.

The **ophthalmic veins** (fig. 780), two in number, superior and inferior, are devoid of valves.

The *superior ophthalmic vein* begins behind the medial angle of the upper eyelid by the union of two branches which communicate anteriorly with the anterior facial and supra-orbital veins (p. 806). It runs with the ophthalmic artery, receives tributaries corresponding to the branches of that vessel, passes through the medial part of the superior orbital fissure, and ends in the cavernous sinus.

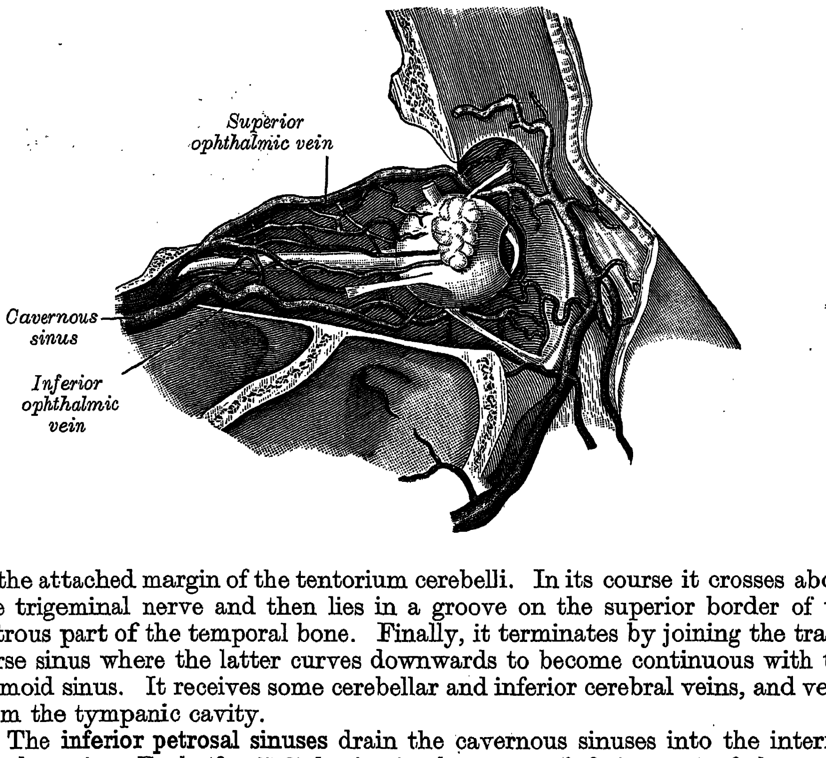
The *inferior ophthalmic vein* begins in a venous network at the fore part of the floor and medial wall of the orbit; it receives some veins from the Rectus

inferior, Obliquus inferior, lacrimal sac and eyelids, and runs backwards above the Rectus inferior. It frequently joins the superior ophthalmic vein, but may open into the cavernous sinus. It communicates with the pterygoid venous plexus by means of small veins which pass through the inferior orbital fissure.

The **intercavernous sinuses**, an anterior and a posterior, connect the cavernous sinuses across the median plane, and are situated in the anterior and posterior attached borders of the diaphragma sellæ; they form with the cavernous sinuses a venous circle (*circular sinus*) (fig. 778). The small, irregular venous sinuses which lie below the hypophysis cerebri drain into the intercavernous sinuses.

The **superior petrosal sinuses** (fig. 778), small and narrow, drain the cavernous sinuses into the transverse sinuses. After leaving the posterosuperior part of the cavernous sinus, each superior petrosal sinus runs backwards and laterally

FIG. 780.—The veins of the orbit. (Poirier and Charpy.)



in the attached margin of the tentorium cerebelli. In its course it crosses above the trigeminal nerve and then lies in a groove on the superior border of the petrous part of the temporal bone. Finally, it terminates by joining the transverse sinus where the latter curves downwards to become continuous with the sigmoid sinus. It receives some cerebellar and inferior cerebral veins, and veins from the tympanic cavity.

The **inferior petrosal sinuses** drain the cavernous sinuses into the internal jugular vein. Each (fig. 778) begins in the postero-inferior part of the corresponding cavernous sinus, runs backwards in the groove between the petrous part of the temporal bone and the basilar part of the occipital bone, and, passing through the anterior part of the jugular foramen, ends in the superior bulb of the internal jugular vein. It receives the internal auditory vein and also veins from the medulla oblongata, pons, and under surface of the cerebellum.

The relations of the structures transmitted through the jugular foramen are as follows: the inferior petrosal sinus lies medially and anteriorly with the meningeal branch of the ascending pharyngeal artery, and is directed obliquely downwards and backwards; the sigmoid sinus is situated at the lateral and posterior part of the foramen with a meningeal branch of the occipital artery; between the two sinuses are the glossopharyngeal, vagus, and accessory nerves. The junction of the inferior petrosal sinus with the internal jugular vein usually takes place on the lateral aspect of the nerves.

The **network of basilar sinuses** (fig. 778) consists of several interconnecting venous channels situated between the layers of the dura mater over the dorsum sellæ of the sphenoid bone and the basilar part of the occipital bone; it connects

the two inferior petrosal sinuses, and communicates with the internal vertebral venous plexus.

The **middle meningeal sinuses** (fig. 778) communicate above with the superior sagittal sinus through the adjoining venous lacunæ, and unite to form two principal trunks, an anterior and a posterior, which accompany the branches of the middle meningeal arteries more or less closely in the grooves on the inner surface of the parietal bone; sometimes they occupy grooves apart from the arteries. Their mode of ending is subject to some variation. The posterior trunk may leave the cranial cavity through the foramen spinosum and open into the pterygoid plexus. The anterior trunk may reach the pterygoid plexus by emerging through the foramen ovale, or it may end in the sphenoparietal sinus or in the cavernous sinus. Besides their meningeal tributaries they receive some small inferior cerebral veins, and communicate with the diploic veins and with the superficial middle cerebral vein.

Wood Jones * has pointed out that the grooves on the inner surfaces of the parietal bones are in reality impressed by the middle meningeal sinuses and not by the middle meningeal arteries, and says, " contrary to the general belief of surgeons, the vascular tunnel at the pterion, although it lodges arterial branches, is typically formed by, and typically lodges a venous sinus."

The Emissary Veins

The **emissary veins** pass through apertures in the cranial wall and establish communications between the venous sinuses inside the skull and the veins external to it. Some are constant, but others are not always present. 1. A mastoid emissary vein runs through the mastoid foramen and unites the sigmoid sinus with the posterior auricular or occipital vein. 2. A parietal emissary vein passes through the parietal foramen and connects the superior sagittal sinus with the veins of the scalp. 3. An anterior condylar emissary vein traverses the anterior condylar (hypoglossal) canal and joins the sigmoid sinus with the internal jugular vein. 4. A posterior condylar emissary vein passes through the posterior condylar canal and connects the sigmoid sinus with the veins in the suboccipital triangle. 5. A network of emissary veins unites the cavernous sinus with the pterygoid plexus through the foramen ovale. 6. Two or three small emissary veins run through the foramen lacerum and connect the cavernous sinus with the pterygoid plexus. 7. A vein traverses the emissary sphenoidal foramen (of Vesalius) and connects the same vessels. 8. A plexus of veins accompanies the internal carotid artery through the carotid canal of the temporal bone and unites the cavernous sinus with the internal jugular vein. 9. The petrosquamous sinus (p. 817) connects the transverse sinus with the external jugular vein. 10. An emissary vein may pass through the foramen cæcum, which, however, is only patent in a little over 1 per cent. of adult skulls,† and connect the veins of the nose with the superior sagittal sinus.

Applied Anatomy.—These emissary veins are of importance in surgery. Inflammatory processes commencing on the outside of the skull may travel inwards through them, and lead to thrombosis of the sinuses.

By means of these emissary veins blood may be abstracted from the intracranial circulation—e.g. leeches applied behind the ear drain blood from the transverse sinus through the mastoid vein.

THE VEINS OF THE UPPER LIMB AND THORAX

The veins of the upper limb are divided into two sets, *superficial* and *deep*, which anastomose freely with each other. The superficial veins are placed immediately under the skin, in the superficial fascia; the deep veins accompany the arteries. Both sets are provided with valves, which are more numerous in the deep than in the superficial veins.

* *Journal of Anatomy and Physiology*, vol. xlvi.

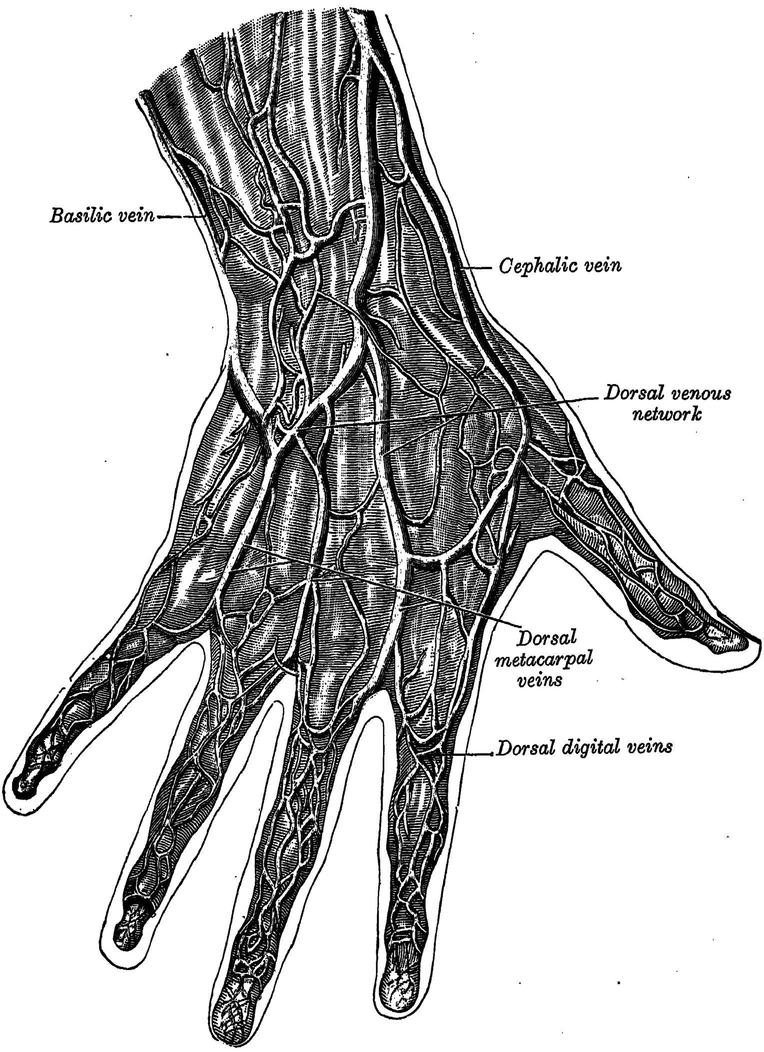
† G. I. Boyd, *Journal of Anatomy*, vol. lxv. 1930.

THE SUPERFICIAL VEINS OF THE UPPER EXTREMITY (figs. 781, 782)

The **superficial veins** of the upper limb are the cephalic, basilic, and median antebrachial veins, and their tributaries.

The *dorsal digital veins* pass along the sides of the fingers and are joined to one another by oblique communicating branches. Those from the adjacent sides of the fingers unite to form three *dorsal metacarpal veins* (fig. 781), which end in a *dorsal venous network* opposite the middle of the metacarpus. The

FIG. 781.—The veins of the dorsum of the hand. (Bourgery.)



radial part of the network is joined by the dorsal digital vein from the radial side of the index finger and by the dorsal digital veins of the thumb, and is prolonged upwards as the cephalic vein. The ulnar part of the network receives the dorsal digital vein of the ulnar side of the little finger and is continued upwards as the basilic vein. A communicating branch frequently connects the dorsal venous network with the cephalic vein about the middle of the forearm.

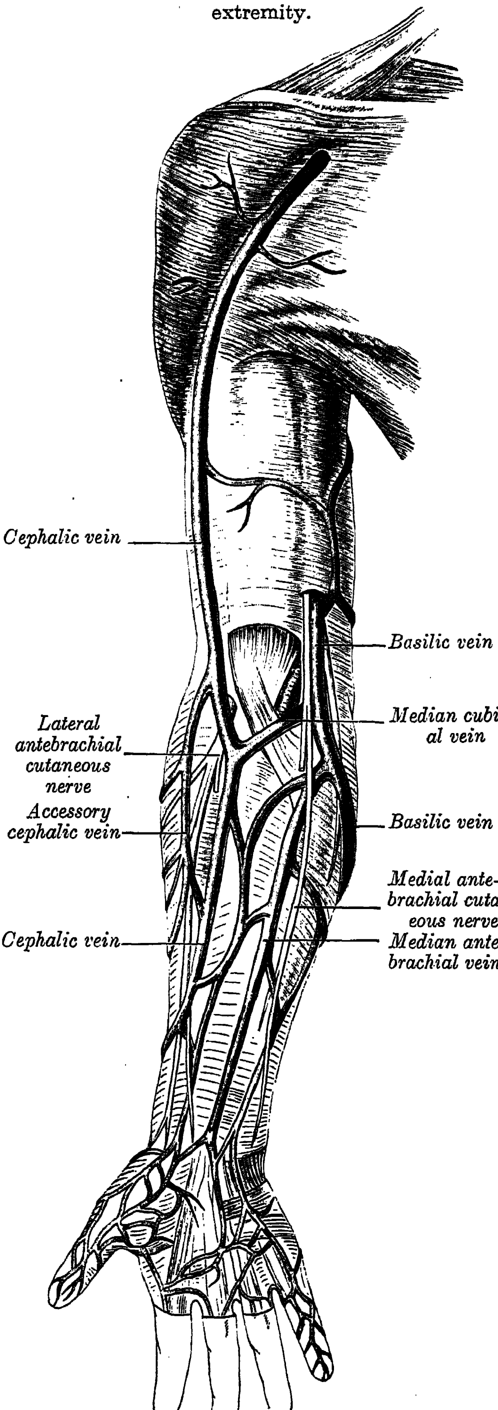
The *palmar digital veins* are connected to the dorsal digital veins by oblique *intercapitular veins*, which pass backwards between the heads of the metacarpal bones. They also drain into a venous plexus which lies superficial to the palmar aponeurosis, and extends over the thenar and hypothenar eminences.

The **cephalic vein** (fig. 782) begins in the radial part of the dorsal venous network of the hand and winds upwards round the radial border of the forearm to its anterior surface, receiving tributaries from both surfaces. Below the front of the elbow it gives off the *median cubital vein*, which receives a communicating branch from the deep veins of the forearm and passes medially to join the basilic vein. The cephalic vein then ascends in front of the elbow in the groove between the Brachioradialis and the Biceps. It crosses superficial to the lateral antebrachial cutaneous nerve and runs upwards along the lateral border of the Biceps. In the upper one-third of the arm it lies in the interval between the Pectoralis major and Deltoid, where it is accompanied by the deltoid branch of the acromio-thoracic artery. Entering the infraclavicular fossa (deltoideo-pectoral triangle), it passes under cover of the clavicular head of the Pectoralis major. It then pierces the clavipectoral fascia, crosses the axillary artery, and ends in the axillary vein just below the clavicle. Sometimes it communicates with the external jugular vein by a branch which ascends in front of the clavicle.

In some cases the median cubital vein is large and carries all or most of the blood from the cephalic into the basilic vein, the result being that the proximal half of the cephalic vein is either absent or of small size.

The *accessory cephalic vein* arises from a small tributary plexus on the back of the forearm or from the ulnar side of the dorsal venous network; it joins the cephalic below the elbow. In some cases it springs from the cephalic vein above the wrist and joins it again higher up. A large oblique branch frequently connects the basilic and cephalic veins on the back of the forearm.

Fig. 782.—The superficial veins of the right upper extremity.



The **basilic vein** (fig. 782) begins in the ulnar part of the dorsal venous network of the hand. It runs up for some distance on the posterior surface of the ulnar side of the forearm but inclines forward to the anterior surface below the elbow. It is joined by the median cubital vein and ascends obliquely in the groove between the Biceps and Pronator teres; filaments of the medial ante-

brachial cutaneous nerve pass both in front of and behind this portion of the vein. It then runs upwards along the medial border of the Biceps, perforates the deep fascia a little below the middle of the upper arm, and, ascending on the medial side of the brachial artery to the lower border of the Teres major, is continued onwards as the axillary vein.

The **median vein of the forearm** (fig. 782) drains the venous plexus on the palmar surface of the hand. It ascends on the front of the forearm and ends in the basilic vein or the median cubital vein ; in a small proportion of cases it divides below the elbow into two branches, one of which joins the basilic vein, the other the cephalic vein.

Applied Anatomy.—Venesection is generally performed at the bend of the elbow, and as a matter of practice the largest vein in this situation, the median cubital, is commonly selected.

Intravenous infusion of normal saline solution is frequently required in modern surgery for conditions of severe shock and after profuse hæmorrhages, when suitable donors are not available for transfusion of blood. The patient's arm is surrounded by a tight bandage so as to impede the venous return, and the largest vein visible in front of the elbow is selected.

The Deep Veins of the Upper Limb

The **deep veins** follow the course of the arteries, and form their venæ comitantes. They are generally arranged in pairs, and are situated one on each side of the corresponding artery, and connected at intervals by short transverse branches. As most of the blood which supplies the upper limb is returned by the superficial veins, the deep veins are small and inconspicuous.

The deep veins of the hand.—The superficial and deep palmar arterial arches are each accompanied by a pair of venæ comitantes, which constitute respectively the *superficial* and *deep palmar venous arches*, and receive the veins corresponding to the branches of the arterial arches ; thus the *palmar digital veins* open into the superficial, and the *palmar metacarpal veins* into the deep, palmar venous arches. The deep veins accompanying the dorsal metacarpal arteries receive perforating branches from the palmar metacarpal veins, and end in the radial veins and in the dorsal venous network.

The **deep veins of the forearm** are the venæ comitantes of the radial and ulnar arteries and constitute respectively the upward continuations of the deep and superficial palmar venous arches ; they unite in front of the elbow to form the brachial veins. The radial veins are smaller than the ulnar, and receive the deep veins of the dorsum of the hand. The ulnar veins receive tributaries from the deep palmar venous arch and communicate with the superficial veins at the wrist ; near the elbow they receive the anterior and posterior interosseous veins and send a large communicating branch (profunda vein) to the median cubital vein.

The **brachial veins** are placed one on each side of the brachial artery, and receive tributaries corresponding with the branches of that artery ; near the lower margin of the Subscapularis, they join the axillary vein ; the medial one frequently joins the basilic vein.

These deep veins have numerous anastomoses, not only with each other, but also with the superficial veins.

The **axillary vein** begins at the lower border of the Teres major, as the continuation of the basilic vein, increases in size as it ascends, and ends at the outer border of the first rib, where it becomes continuous with the subclavian vein. Near the lower border of the Subscapularis it receives the brachial veins and, close to its termination, the cephalic vein ; its other tributaries correspond with the branches of the axillary artery. It lies on the medial side of the axillary artery, which it partly overlaps ; between the two vessels are the medial pectoral (medial anterior thoracic) nerve, the medial cord of the brachial plexus, the ulnar nerve and the medial antebrachial cutaneous nerve. On its medial side it is accompanied by the medial cutaneous nerve of the arm, and both on its medial and posterior aspects it is intimately related to the lateral group of the axillary lymph glands. It is provided with a pair of valves opposite the

lower border of the Subscapularis ; valves are also found in the ends of the cephalic and subscapular veins.

Applied Anatomy.—Since the axillary vein is superficial to and larger than the axillary artery, which it overlaps, it is more liable to be wounded than the artery in the operation of excision of the axillary lymph glands, especially as these glands, when diseased, are apt to become adherent to it.

The **subclavian vein** (fig. 784), which is the continuation of the axillary vein, extends from the outer border of the first rib to the medial border of the Scalenus anterior, where it unites with the internal jugular vein to form the innominate vein. It is in relation, in front, with the clavicle and Subclavius ; behind and above, with the subclavian artery, from which it is separated by the Scalenus anterior and, on the right side, by the phrenic nerve. Below, it rests in a shallow groove on the first rib and upon the pleura. It is usually provided with a pair of valves, which are situated about 2 cm. from its termination.

Its tributaries are the external jugular vein, sometimes the anterior jugular vein, and occasionally a small branch, which ascends in front of the clavicle, from the cephalic vein.

At its angle of junction with the internal jugular vein, the left subclavian vein receives the thoracic duct, and the right subclavian vein the right lymphatic duct.

The Veins of the Thorax (figs. 783, 784)

The **innominate veins** are two large trunks, placed in the root of the neck and in the uppermost part of the thorax ; each is formed by the union of the internal jugular and subclavian veins of the corresponding side and both are devoid of valves.

The **right innominate vein** (fig. 783), about 2·5 cm. long, begins behind the sternal end of the right clavicle, and, passing almost vertically downwards, joins the left innominate vein to form the superior vena cava behind the cartilage of the first rib, close to the right border of the sternum. It lies in front and to the right of the innominate artery and the right vagus nerve. The right pleura, phrenic nerve, and internal mammary artery are posterior to the upper part, and lateral to the lower part of the vein.

Its tributaries are the right vertebral, the right internal mammary and the right inferior thyroid veins, and sometimes the first right posterior intercostal vein.

The **left innominate vein** (fig. 783), about 6 cm. long, begins behind the sternal end of the left clavicle, where it lies in front of the left cervical pleura. It runs obliquely downwards and to the right behind the upper half of the manubrium sterni to the sternal end of the first right costal cartilage, where it unites with the right innominate vein to form the superior vena cava. It is separated from the left sternoclavicular joint and the manubrium sterni by the Sternohyoid and Sternothyroid, the thymus or its remains, and some loose areolar tissue, and, at its termination, is overlapped by the right pleura. In its course it crosses superficial to the left internal mammary, subclavian and common carotid arteries, the left phrenic and vagus nerves, the trachea and the innominate artery. The arch of the aorta lies below the vessel.

Its tributaries are the left vertebral, left internal mammary, left inferior thyroid, and left superior intercostal veins, sometimes the first left posterior intercostal vein and occasionally some thymic and pericardial veins.

Peculiarities.—Sometimes the innominate veins open separately into the right atrium ; in such cases the right vein takes the ordinary course of the superior vena cava ; the left vein—*left superior vena cava,* as it is then termed—which may communicate by a small branch with the right one, crosses the left side of the arch of the aorta, passes in front of the root of the left lung, and, turning to the back of the heart, ends in the right atrium. It replaces the oblique vein of the left atrium and the coronary sinus and receives all the tributaries of the latter vessel. This occasional condition in the adult is due to the persistence of the early fœtal condition (p. 158), and is the normal condition in birds and some mammals.

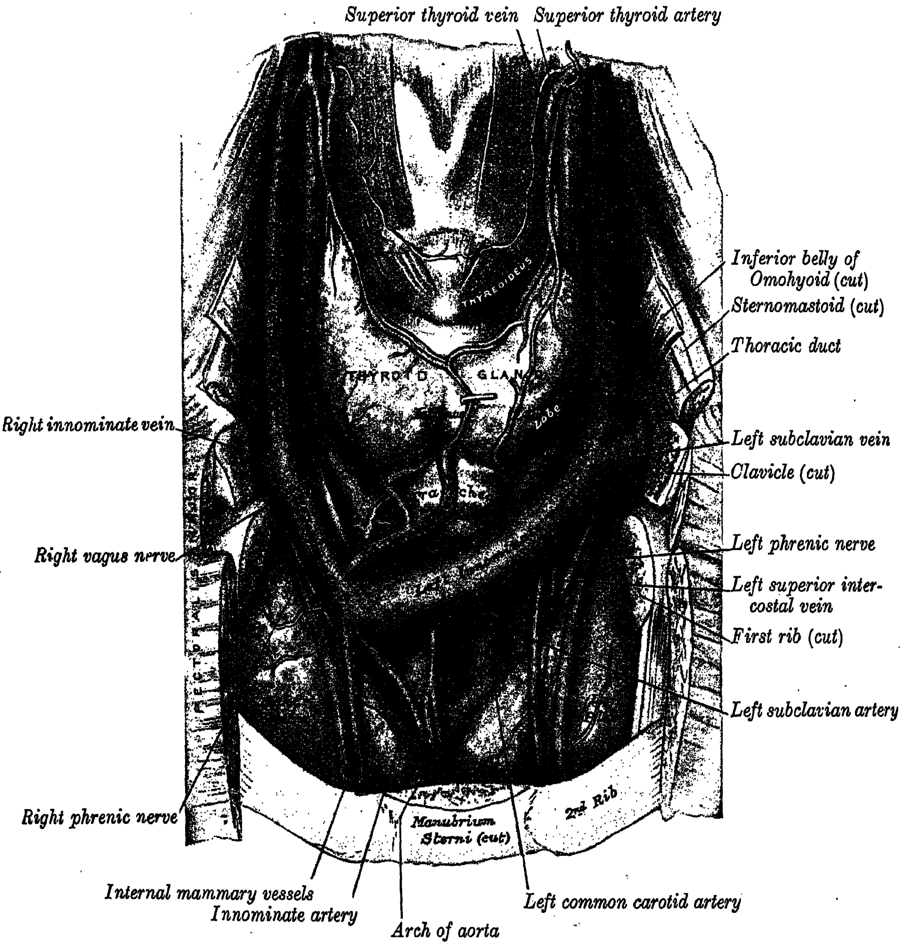
The left innominate vein sometimes projects above the level of the manubrium sterni, crossing the suprasternal fossa, and lying in front of the trachea.

The **internal mammary veins** (figs. 719, 783) are venæ comitantes to the lower half of the internal mammary artery, and are provided with a number of

valves. About the level of the third costal cartilage the venæ comitantes unite to form a single trunk, which runs up medial to the artery and ends in the corresponding innominate vein. They receive as tributaries the veins which accompany the branches of the internal mammary artery (p. 737), and usually the pericardiacophrenic vein.

The **inferior thyroid veins** (figs. 773, 783), two in number, arise in the thyroid gland in a venous network which communicates with the middle and

FIG. 783.—Dissection of the lower part of the neck, and the upper part of the thorax. Anterior aspect.



superior thyroid veins. They form a plexus in front of the trachea. From this plexus the left vein descends and joins the left innominate trunk, and the right vein passes obliquely downwards and to the right across the innominate artery to open into the right innominate vein, at its junction with the superior vena cava; frequently the two veins open by a common trunk in the latter situation. Not infrequently this common trunk terminates in the left innominate vein. These veins receive œsophageal, tracheal, and inferior laryngeal veins, and are provided with valves at their terminations.

The **left superior intercostal vein** (fig. 784) receives the second and third (and sometimes the fourth) left posterior intercostal veins; it runs obliquely upwards and forwards on the left side of the aortic arch, passing lateral to the left vagus and medial to the left phrenic nerve, and opens into the left innominate vein. It usually receives the left bronchial veins, and sometimes the left pericardiacophrenic vein; it communicates below with the superior hemiazygos (accessory hemiazygos) vein. Occasionally it gives off, near its termination, a small

vessel which runs downwards across the aortic arch and behind the left pulmonary artery to enter the ligament of the left vena cava (p. 669). Gaining the dorsal aspect of the left atrium this small vessel becomes continuous with the oblique vein.

The **superior vena cava** (figs. 695, 696, 697, 699) drains the blood from the upper half of the body. It measures about 7 cm. in length, is formed by the junction of the two innominate veins, and is devoid of valves. It begins behind the cartilage of the right first rib close to the sternum, and, descending vertically behind the first and second intercostal spaces, ends in the upper part of the right atrium opposite the third right costal cartilage; the lower half of the vessel is within the fibrous pericardium, which it pierces at the level of the second costal cartilage, and is covered in front and on its sides with the serous pericardium. In its course it describes a slight curve, the convexity of which is to the right side.

Relations.—*In front,* the superior vena cava is related to the anterior margins of the right lung and pleura with the pericardium intervening below; these separate it from the internal mammary artery, and the first and second intercostal spaces, and from the second and third costal cartilages; the trachea and the right vagus nerve are *posteromedial* and the right lung and pleura *posterolateral* to its upper part, while the root of the right lung is a direct posterior relation below. On its *right side,* it is related to the right phrenic nerve and right pleura; on its *left side,* to the commencement of the innominate artery and the ascending aorta, the latter overlapping it.

Tributaries.—The superior vena cava receives the azygos vein and several small veins from the pericardium and other structures in the mediastinum.

The **azygos vein** * (fig. 785) is inconstant in its mode of origin. On morphological grounds it may be expected to arise from the posterior aspect of the inferior vena cava, at or below the level of the renal veins. Such a vein (*lumbar azygos*) is very frequently present and ascends in front of the upper lumbar vertebræ. It may pass deep to the lateral border of the right crus of the diaphragm, or it may pierce the crus, or it may occasionally pass through the aortic opening of the diaphragm, on the right side of the cisterna chyli. In front of the body of the twelfth thoracic vertebra, it is joined by a large vessel which, formed by the union of the right ascending lumbar with the right subcostal vein, passes forwards on the right side of the body of the twelfth thoracic vertebra under cover of the right crus of the diaphragm. This common trunk may, in the absence of a lumbar azygos vein, form the azygos vein. Whatever its mode of origin, the azygos vein ascends in the posterior mediastinum to the level of the fourth thoracic vertebra where it arches forward over the root of the right lung, and ends in the superior vena cava, just before that vessel pierces the pericardium. In its course it lies in front of the bodies of the lower eight thoracic vertebræ, the anterior longitudinal ligament, and the right posterior (aortic) intercostal arteries. On its right side are the greater splanchnic nerve, the right lung and pleura; on its left side, throughout the greater part of its course, are the thoracic duct and aorta, and higher up, where it arches forward above the root of the right lung, the œsophagus, trachea and right vagus. In the lower part of the thorax it is covered anteriorly by a recess of the right pleural sac and by the œsophagus, but it emerges from behind the right edge of the latter and ascends behind the hilum of the right lung.

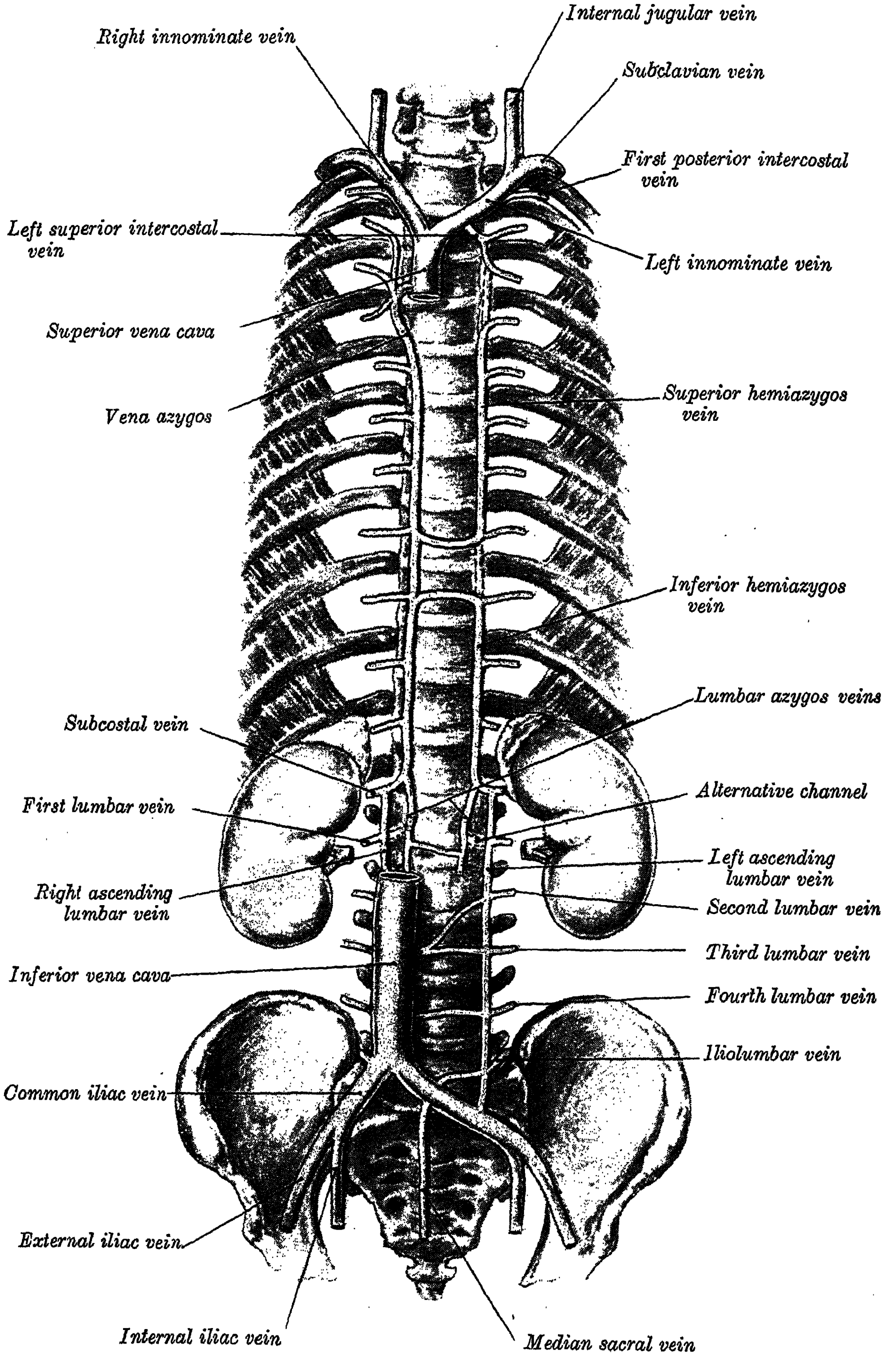
Tributaries.—It receives the posterior intercostal veins of the right side, with the exception of the vein from the first intercostal space; the veins from the second, third and fourth intercostal spaces open by a common stem called the right superior intercostal vein. It receives also the superior and inferior hemiazygos veins, several œsophageal, mediastinal, and pericardial veins, and, near its termination, the right bronchial veins. When it begins as a lumbar azygos vein, the common trunk formed by the union of the right ascending lumbar and subcostal veins is its largest tributary. A few imperfect valves are found in the azygos vein; but its tributaries are provided with complete valves.

The **inferior hemiazygos vein** * (hemiazygos vein) (fig. 784) arises on the left side in a manner corresponding to the origin of the azygos vein on the right

* The arrangement of the rootlets of the azygos and hemiazygos veins is subject to a wide range of variation. See R. J. Gladstone, *Journal of Anatomy,* vol. lxiv. 1929.

side and, ascending on the front of the vertebral column as high as the eighth thoracic vertebra, passes across the column, behind the aorta, œsophagus, and

Fig. 784.—The azygos, hemiazygos and ascending lumbar veins, their tributaries and connexions.

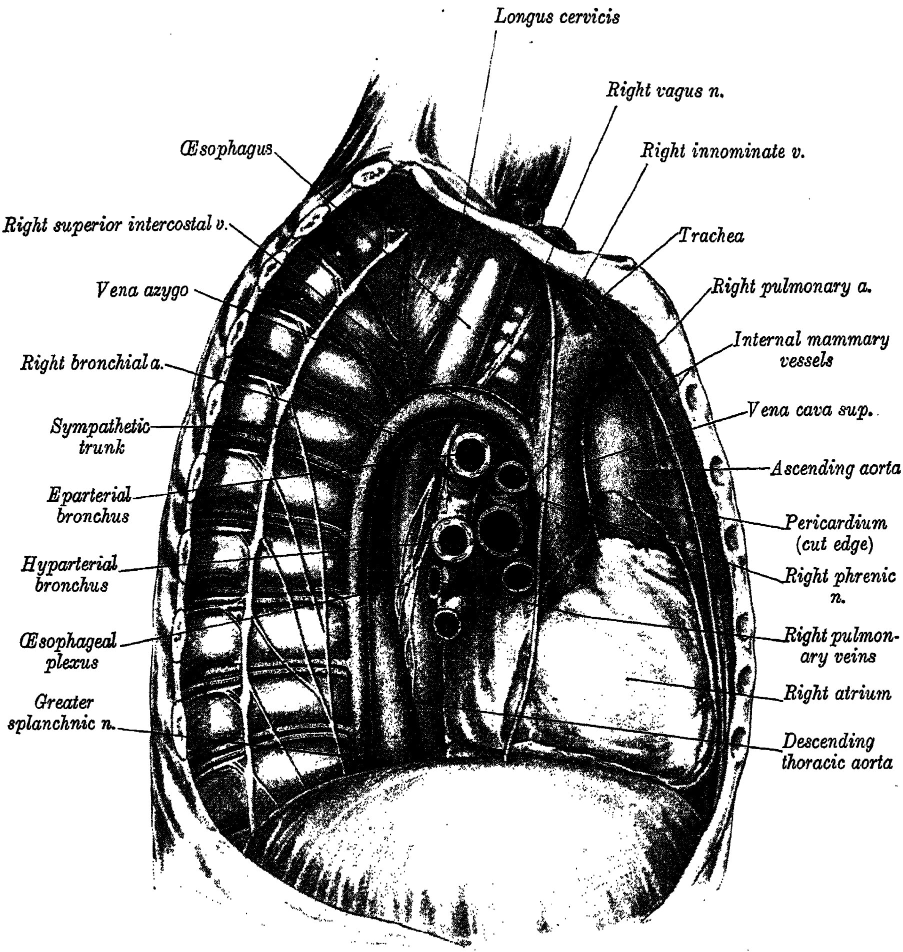


N.B.—On both sides the first lumbar vein is shown terminating in the ascending lumbar vein, but its occasional termination in the lumbar azygos vein is indicated as well.

thoracic duct, to end in the azygos vein. It receives the lower three posterior intercostal veins and the common trunk formed by the union of the ascending lumbar and the subcostal veins of the left side, and some œsophageal and mediastinal veins.

The **superior hemiazygos vein** (accessory hemiazygos vein) (fig. 784) descends on the left side of the vertebral column. It receives the veins from the fourth (or fifth) to the eighth intercostal spaces inclusive, and sometimes the left bronchial veins. It crosses the body of the seventh thoracic vertebra and joins the azygos vein. The superior hemiazygos vein sometimes joins the inferior hemiazygos vein, and the common trunk thus formed opens into the azygos vein.

FIG. 785.—The mediastinum, dissected from the right side.



A portion of the pericardial sac has been removed in order to expose the lateral aspect of the right atrium.
In this specimen the fourth right posterior intercostal vein did not join the superior intercostal vein, the œsophagus was somewhat dilated and an unusually large extent of the descending thoracic aorta was visible from the right side.

The **posterior intercostal veins** (figs. 737, 784, 785) run with the posterior (aortic) intercostal arteries and are eleven in number on each side. As they approach the vertebral column each vein receives a tributary which accompanies the posterior branch of the corresponding artery and returns blood from the muscles and skin of the back and from the vertebral venous plexuses.

On both sides of the thorax the first posterior intercostal vein ascends in front of the neck of the first rib and, arching forwards above the pleura, ends in the corresponding innominate or vertebral vein.

On the right side the second, third and, often, the fourth posterior intercostal veins unite to form the *right superior intercostal vein*, which joins the terminal part of the azygos vein. The veins from the intercostal spaces below the fourth open separately into the vena azygos.

On the left side the second and third (and sometimes the fourth) posterior intercostal veins unite to form the left superior intercostal vein (p. 826). The veins from the fourth (or fifth) to the eighth intercostal spaces inclusive end in the superior hemiazygos vein, and the veins from the lower three spaces in the inferior hemiazygos vein.

The posterior intercostal veins are called 'posterior' to distinguish them from the small *anterior intercostal veins*, which are tributaries of the internal mammary and musculophrenic veins.

Applied Anatomy.—In obstruction of the superior vena cava, the azygos and hemiazygos veins are one of the principal means by which the venous circulation is carried on, connecting, as they do, the superior and inferior venæ cavæ, and communicating with the common iliac veins by the ascending lumbar veins, and with many of the tributaries of the inferior vena cava.

The **bronchial veins**, usually two on each side, return the blood from the larger bronchi, and from the structures at the roots of the lungs. The bronchial veins of the right side open into the terminal part of the vena azygos; those of the left side, into the left superior intercostal vein or the superior hemiazygos vein. Some of the blood carried to the lungs through the bronchial arteries is returned to the heart through the pulmonary veins.

The Veins of the Vertebral Column (figs. 786, 787)

The veins of the vertebral column form intricate plexuses extending along the entire length of the column; these plexuses are divisible into two groups, termed external and internal, according to their positions outside or inside the vertebral canal. The plexuses of the two groups anastomose freely with each other, and end in the intervertebral veins.

The **external vertebral venous plexuses**, best marked in the cervical region, consist of anterior and posterior plexuses, which anastomose freely with each other. The *anterior external plexuses* lie in front of the bodies of the vertebræ, communicate with the basivertebral and intervertebral veins, and receive tributaries from the vertebral bodies. The *posterior external plexuses* are placed on the posterior surfaces of the laminæ and around the spines and the transverse and articular processes. They anastomose with the internal vertebral venous plexuses, and end in the vertebral, posterior intercostal and lumbar veins.

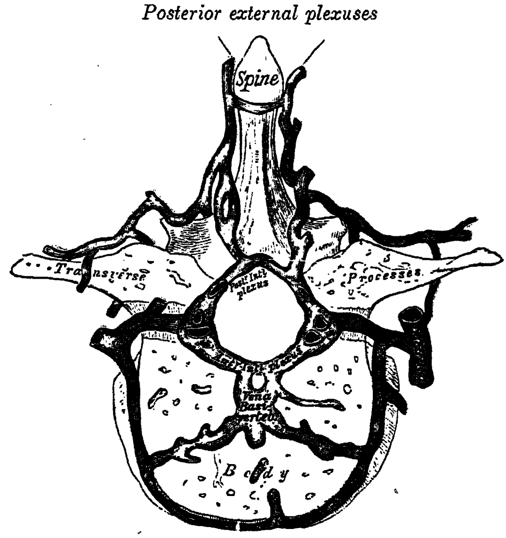
The **internal vertebral venous plexuses** lie within the vertebral canal between the dura mater and the vertebræ, and receive tributaries from the bones and from the spinal cord. They form a closer network than the external plexuses, and, running mainly in a vertical direction, form four longitudinal veins, two in front and two behind; they therefore may be divided into anterior and posterior groups. The *anterior internal plexuses* consist of large veins which lie on the posterior surfaces of the vertebral bodies and intervertebral discs, on each side of the posterior longitudinal ligament; under cover of this ligament they are connected by transverse branches into which the basivertebral veins open. The *posterior internal plexuses* are placed one on each side of the median plane in front of the vertebral arches and ligamenta flava, and anastomose, by veins passing through those ligaments, with the posterior external plexuses.

The anterior and posterior internal plexuses communicate freely with one another by a series of venous rings, one opposite each vertebra. Around the foramen magnum they form an intricate network, which opens into the vertebral veins and is connected above with the occipital and sigmoid sinuses, the network of basilar sinuses, and with the anterior and posterior condylar emissary veins.

The **basivertebral veins** emerge from the foramina on the posterior surfaces of the vertebral bodies. They are contained in large, tortuous channels in the substance of the bones, similar in every respect to those found in the diploë of the cranial bones. They communicate with the anterior external vertebral plexuses through small openings on the front and sides of the bodies of the

vertebræ, and converge behind to form single (sometimes double) veins, which open by valved orifices into the transverse branches uniting the anterior internal vertebral plexuses. The basivertebral veins become enlarged in advanced age.

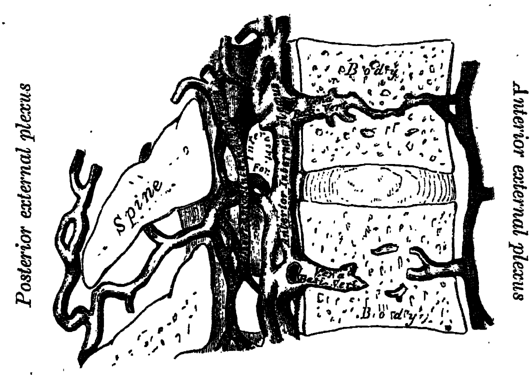
FIG. 786.—A transverse section through a thoracic vertebra, showing the vertebral venous plexuses.



The **intervertebral veins** accompany the spinal nerves through the intervertebral foramina; they receive veins from the spinal cord, drain the internal and external vertebral plexuses and end in the vertebral, posterior intercostal, lumbar and lateral sacral veins, their orifices being provided with valves.

The **veins of the spinal cord** are situated in the pia mater and form a tortuous venous plexus in this membrane. In this plexus there are: (*a*) two median

FIG. 787.—A median sagittal section through two thoracic vertebræ, showing the vertebral venous plexuses.



longitudinal veins, one in front of the anterior median fissure, and the other behind the posterior septum of the spinal cord; and (*b*) two anterolateral and two posterolateral longitudinal veins, which run behind the anterior and the posterior nerve-roots respectively. They communicate with the internal vertebral venous plexuses, and with the intervertebral veins. Near the base of the skull they unite to form two or three small trunks, which communicate with the vertebral veins, and end in the inferior cerebellar veins, or in the inferior petrosal sinuses.

THE VEINS OF THE LOWER LIMB, ABDOMEN AND PELVIS

The veins of the lower limb are subdivided, like those of the upper limb, into two sets, *superficial* and *deep* : the superficial veins are placed immediately under the skin in the superficial fascia ; the deep veins accompany the arteries. Both sets are provided with valves, which are more numerous in the deep than in the superficial veins. Valves are more plentiful in the veins of the lower than in those of the upper limb.

The Superficial Veins of the Lower Limb

The **superficial veins** of the lower limb are the long and short saphenous veins and their tributaries.

The *dorsal digital veins* receive, in the clefts between the toes, communications from the plantar digital veins, and then join to form *dorsal metatarsal veins*, which unite across the distal ends of the metatarsal bones in a *dorsal venous arch*. Proximal to this arch there is an irregular dorsal venous network, which receives tributaries from the deep veins and is continuous with the venous network on the front of the leg. At the sides of the foot this network communicates with a *medial* and a *lateral marginal vein*, both of which are formed mainly by the union of veins from the superficial parts of the sole of the foot.

On the sole of the foot the superficial veins form a *plantar cutaneous venous arch*, which extends across the roots of the toes and opens at the sides of the foot into the medial and lateral marginal veins. Proximal to this arch there is a *plantar cutaneous venous network*, which is especially dense in the fat beneath the heel ; this network communicates with the plantar cutaneous venous arch and with the deep veins, but is chiefly drained into the medial and lateral marginal veins.

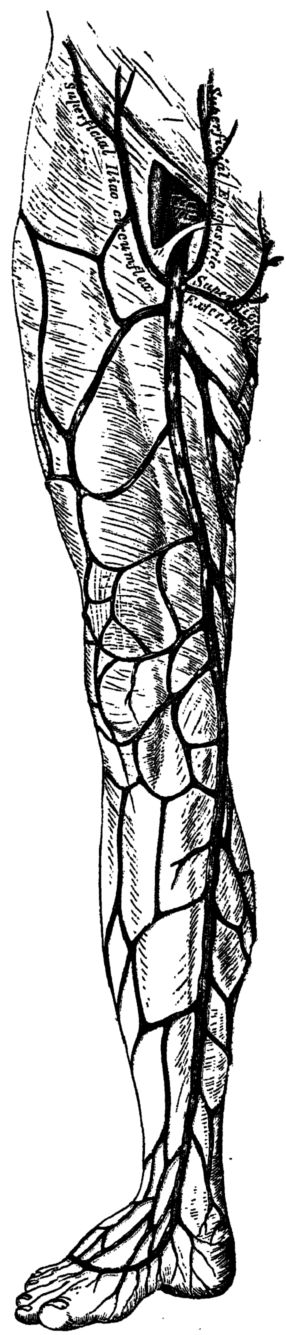
The **long saphenous vein** (great saphenous vein) (fig. 788), the longest vein in the body, begins in the medial marginal vein of the foot, and ends in the femoral vein about 3 cm. below the inguinal ligament. It ascends in front of the tibial malleolus and runs upwards, crossing the medial surface of the tibia obliquely to gain its medial border, along which it ascends to the knee. It runs upwards on the posterior parts of the medial condyles of the tibia and femur and along the medial side of the thigh and, passing through the saphenous opening (fossa ovalis) (p. 624), ends in the femoral vein. In the thigh it is accompanied by some branches of the medial femoral cutaneous nerve, at the knee by the saphenous branch of the descending genicular artery, and in the leg and foot by the saphenous nerve, which is placed in front of the vein. The long saphenous vein is often duplicated, especially below the knee. The valves in it number from ten to twenty and are more numerous in the leg than in the thigh.

Tributaries.—At the ankle it receives veins from the sole of the foot through the medial marginal vein ; in the leg it communicates freely with the short saphenous vein and with the anterior and posterior tibial veins, and receives many cutaneous veins ; in the thigh it receives numerous tributaries ; those from the medial and posterior parts of the thigh frequently unite to form a large *accessory saphenous vein*, which joins the main vein at a variable level. Near the saphenous opening (fig. 788) it is joined by the superficial epigastric, superficial circumflex iliac and external pudendal veins. The superficial epigastric and superficial circumflex iliac veins drain the lower part of the abdominal wall, the latter vein also receiving tributaries from the upper and lateral parts of the thigh ; the external pudendal veins drain part of the scrotum and one is joined by the superficial dorsal vein of the penis.

A vein, named the *thoraco-epigastric*, runs along the anterolateral wall of the trunk, connecting the superficial epigastric vein, or the femoral vein, with the lateral thoracic veins and establishing a communication between the femoral and axillary veins. The importance of this communication lies in the fact that it serves as a connecting channel between the superior and the inferior vena caval fields of drainage.

The **short saphenous vein** (small saphenous vein) (fig. 789) begins behind the lateral malleolus as a continuation of the lateral marginal vein of the foot; it first ascends on the lateral border of the tendo calcaneus, and then along the middle of the back of the leg. It perforates the deep fascia in the lower part of the popliteal fossa, and ends in the popliteal vein from 3 to 7·5 cm. above the level of the knee-joint. It communicates with the deep veins on the dorsum of the foot, receives numerous tributaries from the back of the leg, and sends several branches upwards and medially to join the long saphenous vein. In the leg the vein is in close relation with the sural nerve.

Fig. 788.—The long saphenous vein and its tributaries.



The short saphenous vein possesses from seven to thirteen valves, one of which is found near its termination in the popliteal vein.

The mode of ending of the short saphenous vein is subject to considerable variations. It may join the long saphenous vein in the upper one-third of the thigh, or may divide into two branches, one of which joins the long saphenous vein, the other the popliteal vein or the deep posterior veins of the thigh; occasionally it ends, below the level of the knee-joint, in the long saphenous vein or in the deep muscular veins of the calf.*

Applied Anatomy.—A varicose condition is more frequently met with in the saphenous veins than in the other veins of the body, except perhaps the testicular and rectal veins. The main cause of this is the high blood-pressure, determined chiefly by the erect position, and the length of the column of blood, which has to be propelled in an uphill direction. In normal vessels there is only just sufficient force to perform this task; and in those cases where there is diminished resistance of the walls of the veins, these vessels are liable to dilate and a varicose condition is set up. Increased blood-pressure in the veins, caused by any obstacle to the return of the venous blood, such as the pressure of a tumour, or the gravid uterus, or tight gartering, may also produce varix. In the normal condition of the veins, the valves in their interior break up the column of blood into a number of smaller columns, and so to a considerable extent mitigate the ill effects of the erect position; but when the dilatation of the veins has reached a certain limit, the valves become incapable of supporting the overlying column of blood, and the pressure is increased, tending to emphasise also the varicose condition.

Excision of portions of the dilated veins, with or without ligature of the long saphenous vein at a higher level, used to be practised for this condition. The modern method of treatment† aims at obliteration of the vessels concerned by the injection into them of chemical irritants, such as quinine hydrochloride or salicylic acid. A short length of vein is temporarily occluded and a few c.cs. of the material injected. A non-suppurative phlebitis ensues, which is followed by permanent fibrosis of the vessel. Since the flow of blood in these veins tends to be reversed, there is no fear of embolism.

* Consult an article by C. Kosinski, *Proceedings of the Anatomical Society of Great Britain and Ireland*, February, 1925.

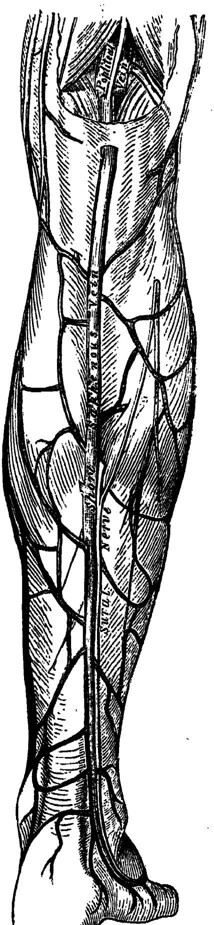
† Sicard and Gangier, *La Presse Médicale*, June, 1926.

The Deep Veins of the Lower Extremity

The **deep veins** of the lower extremity accompany the arteries and their branches; they possess numerous valves.

The *plantar digital veins* arise from plexuses on the plantar surfaces of the digits, and, after sending communications to join the dorsal digital veins, unite to form four *plantar metatarsal veins*; these run backwards in the metatarsal spaces, communicate, by means of perforating veins, with the veins on the dorsum of the foot, and unite to form the *deep plantar venous arch*, which lies alongside the plantar arterial arch. From the deep plantar venous arch the *medial* and *lateral plantar veins* run backwards close to the corresponding arteries and, after communicating with the long and short saphenous veins, unite behind the medial malleolus to form the posterior tibial veins.

Fig. 789.—The short saphenous vein.



The **posterior tibial veins** accompany the posterior tibial artery, and are joined by the *peroneal veins*.

The **anterior tibial veins** are the upward continuations of the venæ comitantes of the dorsalis pedis artery. They leave the front of the leg by passing between the tibia and fibula, through the upper part of the interosseous membrane of the leg, and unite with the posterior tibial veins to form the *popliteal vein*.

The **popliteal vein**, formed by the junction of the anterior and posterior tibial veins at the lower border of the Popliteus, ascends through the popoliteal fossa to the aperture in the Adductor magnus, where it becomes the femoral vein. In the lower part of its course it is medial to the popliteal artery; between the heads of the Gastrocnemius it is superficial to it; above the knee-joint it is posterolateral to it. Its tributaries are the short saphenous vein and the veins corresponding to the branches of the popliteal artery. There are usually four valves in the popliteal vein.

The **femoral vein** accompanies the femoral artery, beginning at the opening in the Adductor magnus, as the continuation of the popliteal vein, and ending at the level of the inguinal ligament, by becoming the external iliac vein. In the lower part of the subsartorial (adductor) canal it is posterolateral to the femoral artery; in the upper part of the canal, and in the lower part of the femoral triangle, it is behind the artery. At the base of the femoral triangle it is medial to the artery (figs. 755, 758); here it occupies the middle compartment of the femoral sheath, and is placed between the femoral artery and the femoral canal. It receives numerous muscular tributaries, and about 4 cm. below the inguinal ligament is joined on its posterior aspect by the vena profunda femoris, and a little higher by the long saphenous vein, which enters its anterior aspect. In addition, it usually receives the lateral and medial circumflex femoral veins. A valve, which may be single or double, is placed at the upper end of the femoral vein, and another is usually present above the opening of its profunda femoris tributary.

The *vena profunda femoris* usually lies superficial to the profunda femoris artery; it receives tributaries corresponding to the muscular and perforating branches of that artery, and through these establishes communications with the popliteal vein below and the inferior gluteal vein above. It sometimes receives the medial and lateral circumflex femoral veins.

The Veins of the Abdomen and Pelvis (figs. 738, 790)

The **external iliac vein**, the upward continuation of the femoral vein, begins behind the inguinal ligament, and ascends along the brim of the true pelvis,

to a point opposite the sacro-iliac joint, where it unites with the internal iliac (hypogastric) vein to form the common iliac vein. On the right side, it lies at first medial to the artery; but, as it passes upwards, gradually inclines behind it. On the left side, it lies altogether on the medial side of the artery. On its medial aspect, it is crossed by the vas deferens (ductus deferens), in the male, the ureter and the internal iliac artery; elsewhere it is covered with peritoneum. In the female it is crossed by the round ligament of the uterus and the ovarian vessels. Posteriorly it is related to the obturator nerve and, laterally to the Psoas major muscle, except where the external iliac artery intervenes. It frequently contains one, sometimes two, valves.

Tributaries.—It receives the inferior epigastric, deep circumflex iliac and pubic veins.

The **inferior epigastric vein** is formed by the union of the venæ comitantes of the inferior epigastric artery, which communicate above with the superior epigastric vein; it joins the external iliac vein about 1 cm. above the inguinal ligament.

The **deep circumflex iliac vein** is formed by the union of the venæ comitantes of the deep circumflex iliac artery, and joins the external iliac vein about 2 cm. above the inguinal ligament after crossing in front of the external iliac artery.

The **pubic vein,** which connects the external iliac with the obturator vein in the obturator foramen, ascends on the pelvic surface of the pubis alongside the pubic branch of the inferior epigastric artery. It is frequently enlarged and replaces the normal obturator vein.

The **internal iliac vein** (hypogastric vein) begins near the upper part of the greater sciatic foramen, ascends behind and slightly medial to the internal iliac artery, and, at the brim of the pelvis, joins with the external iliac vein to form the common iliac vein. It lies in front of the lower part of the sacro-iliac joint and is covered with peritoneum on its anteromedial aspect.

Tributaries.—With the exception of the iliolumbar vein, which usually joins the common iliac vein, the tributaries of the internal iliac vein correspond with the branches of the internal iliac artery. It receives (*a*) the gluteal, internal pudendal, and obturator veins, which have their origins outside the pelvis; (*b*) the lateral sacral veins, which lie in front of the sacrum; and (*c*) the middle rectal, the vesical, uterine, and vaginal veins, which originate in venous plexuses connected with the pelvis viscera.

1. The **superior gluteal veins** are the venæ comitantes of the superior gluteal artery; they receive tributaries from the buttock corresponding with the branches of the artery, enter the pelvis through the greater sciatic foramen, above the Piriformis, and end in the internal iliac vein; they frequently unite to form a single trunk before ending in this vein.

2. The **inferior gluteal veins** are the venæ comitantes of the inferior gluteal artery; they begin on the upper part of the back of the thigh, where they anastomose with the medial circumflex femoral and first perforating veins; they enter the pelvis through the lower part of the greater sciatic foramen and join to form a stem which opens into the lower part of the internal iliac vein.

3. The **internal pudendal veins** are the venæ comitantes of the internal pudendal artery. They begin in the prostatic venous plexus (p. 836), accompany the internal pudendal artery, and unite to form a single vessel, which ends in the internal iliac vein. They receive the veins from the bulb of the penis, and the scrotal or labial and inferior rectal veins. The deep dorsal vein of the penis and the dorsal vein of the clitoris communicate with the internal pudendal veins, but end mainly in the prostatic plexus.

4. The **obturator vein** begins in the upper portion of the adductor region of the thigh, and enters the pelvis through the upper part of the obturator foramen. It runs backwards and upwards on the lateral wall of the pelvis below the obturator artery and lateral to the peritoneum; it passes between the ureter and the internal iliac artery, and ends in the internal iliac vein. Sometimes it is replaced by an enlarged pubic vein, which joins the external iliac vein.

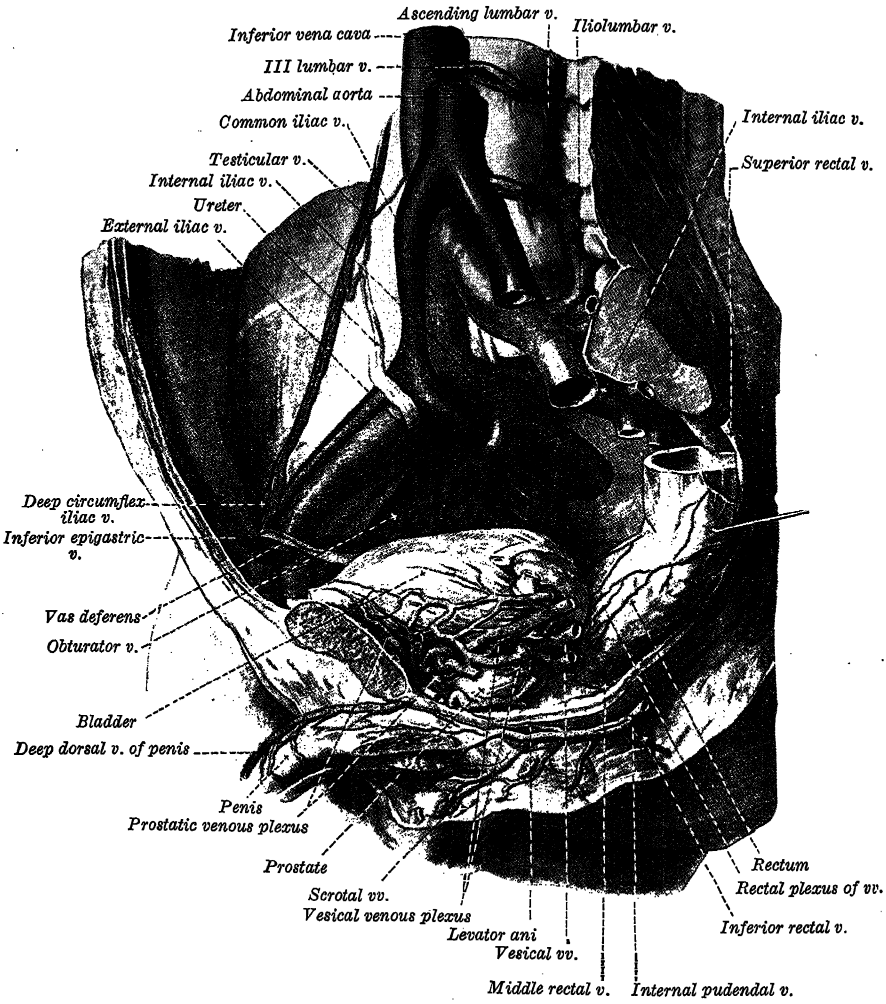
5. The **lateral sacral veins** accompany the lateral sacral arteries and end in the internal iliac vein.

6. The **middle rectal vein** (middle hæmorrhoidal vein) varies in size; it begins in the rectal venous plexus, and receives tributaries from the bladder,

prostate and seminal vesicle; it runs laterally on the pelvic surface of the Levator ani and ends in the internal iliac vein.

The **rectal venous plexus** (hæmorrhoidal plexus) surrounds the rectum, and communicates in front with the vesical plexus in the male, and the uterovaginal plexus in the female. It consists of two parts, an *internal* in the submucosa, and an *external* outside the muscular coat of the rectum and anal canal. The internal

FIG. 790.—The veins of the right half of the male pelvis. (Spalteholz.)



plexus presents a series of dilated pouches, connected by transverse branches, which are arranged in a circle around the tube, immediately above the anal orifice. It drains mainly into the superior rectal vein but communicates freely with the external plexus. The lower part of the external plexus is drained by the inferior rectal veins into the internal pudendal vein; the middle part by the middle rectal vein into the internal iliac vein; and the upper part by the superior rectal vein, which forms the commencement of the inferior mesenteric vein, a tributary of the portal vein. A free communication between the portal and systemic venous systems is established through the rectal plexus.

The **prostatic venous plexus** (pudendal plexus) lies behind the inferior pubic ligament and the lower part of the symphysis pubis, and in front of the bladder and prostate. Its chief tributary is the deep dorsal vein of the penis, but it

also receives tributaries from the front of the bladder and prostate. It communicates with the vesical plexus and with the internal pudendal vein, and drains into the vesical and internal iliac veins. The *prostatic veins* form a well-marked plexus, which lies partly in the fascial sheath of the prostate and partly between the sheath and the prostatic capsule; they communicate with the prostatic and vesical plexuses.

The **vesical plexus** envelops the lower part of the bladder and, in the male, the base of the prostate. It communicates with the prostatic plexus in the male, and with the vaginal plexus in the female. It is drained, by means of several vesical veins, into the internal iliac veins.

Applied Anatomy.—The veins of the rectal plexus are apt to become dilated and varicose, and form piles. This is due to several anatomical reasons: the vessels are contained in very loose connective tissue, so that they get less support from surrounding structures than most other veins, and are less capable of resisting increased blood-pressure; the condition is favoured by the fact that the superior rectal and portal veins have no valves; the veins pass through muscular tissue and are liable to be compressed by its contraction, especially during the act of defæcation; they are affected by every form of portal obstruction.

The **dorsal veins of the penis** are two in number, a superficial and a deep: The *superficial dorsal vein* drains the prepuce and skin of the penis, and, running backwards in the subcutaneous tissue, inclines to the right or left, and opens into the corresponding external pudendal vein, a tributary of the long saphenous vein. The *deep dorsal vein* lies within the fibrous envelope of the penis; it receives blood from the glans penis and corpora cavernosa penis, and courses backwards in the median plane between the dorsal arteries; near the root of the penis it passes between the two parts of the suspensory ligament and then through an aperture between the inferior pubic ligament and the anterior margin of the perineal membrane, and divides into two branches, which enter the prostatic plexus. It also communicates below the symphysis pubis with the internal pudendal vein. The *dorsal vein of the clitoris*, after a similar course to that of the deep dorsal vein of the penis, ends in the vesical plexus.

The **uterine plexuses** lie along the sides and superior angles of the uterus between the two layers of the broad ligament, and communicate with the ovarian and vaginal plexuses. They are drained by a pair of uterine veins on each side; these arise from the lower parts of the plexuses, opposite the external os of the uterus, and open into the corresponding internal iliac vein.

The **vaginal plexuses** are placed at the sides of the vagina; they communicate with the uterine, vesical and rectal plexuses, and are drained by the vaginal veins, one on each side, into the internal iliac veins.

The **common iliac veins** (fig. 790) are formed by the union of the external and internal iliac veins, in front of the sacro-iliac joint; passing obliquely upwards they end on the right side of the fifth lumbar vertebra by uniting with each other at an acute angle to form the inferior vena cava. The *right common iliac vein,* shorter than the left, is nearly vertical in its direction, and ascends behind, and then lateral to its artery. The right obturator nerve passes behind it obliquely, as it runs downwards and forwards to the obturator foramen. The *left common iliac vein,* longer and more oblique than the right, is at first situated on the medial side of its artery, and then behind the right common iliac artery. It is crossed anteriorly by the root of the pelvic mesocolon and the superior rectal vessels. In the rest of its course it is covered with peritoneum. Each common iliac vein receives the iliolumbar, and sometimes the lateral sacral veins; the left vein receives the median sacral vein. There are no valves in these veins.

The **median sacral veins** (middle sacral veins) accompany the corresponding artery along the front of the sacrum, and join to form a single vein, which usually ends in the left common iliac vein, but sometimes in the angle of junction of the two common iliac veins.

Peculiarities.—The left common iliac vein, instead of joining with the right in its usual position, occasionally ascends on the left side of the aorta as high as the kidney, where, after receiving the left renal vein, it crosses the aorta, and joins the right vein to form the vena cava. In such cases the anomalous vessel represents the persistent caudal half of the posterior cardinal or of the supracardinal vein of the left side.

The **inferior vena cava** (figs. 738, 790) conveys the blood from the parts below the Diaphragm to the right atrium of the heart. It is formed by the junction of the two common iliac veins, in front of the body of the fifth lumbar vertebra, a little to the right of the median plane. It ascends in front of the vertebral column, on the right side of the aorta, and, having reached the liver, is contained in a deep groove on its posterior surface—a groove which is occasionally converted into a tunnel by a band of liver substance. It then perforates the Diaphragm between the median and right portions of its central tendon, inclining slightly forwards and medially. After piercing the fibrous pericardium, it passes behind the serous pericardium to open into the lower and posterior part of the right atrium. In front and to the left of its atrial orifice there is a semilunar valve, termed the *valve of the inferior vena cava* ; this valve is rudimentary in the adult, but is of large size and exercises an important function in the fœtus (p. 674). The trunk of the inferior vena cava is devoid of valves.

Relations of the abdominal portion.—*Anteriorly* the inferior vena cava is overlapped at its commencement by the right common iliac artery and is covered, below the third part of the duodenum, with the posterior parietal peritoneum. It is crossed obliquely by the root of the mesentery and its contained vessels, and by the right testicular artery and, sometimes, transversely by the right colic artery. Passing behind the third part of the duodenum, it loses its peritoneal covering and ascends behind the head of the pancreas and then behind the first part of the duodenum, from which it is separated by the bile duct and the portal vein. Above the duodenum it is again covered for a short distance with peritoneum and lies in the posterior wall of the aditus to the lesser sac (epiploic foramen) (figs. 1162 and 1164), by which it is separated from the right free border of the lesser omentum and its contents. Above this level it is covered by the liver.

Posteriorly, in its lower part, the inferior vena cava lies on the bodies of the lower three lumbar vertebræ and the anterior longitudinal ligament, the right Psoas major and the right sympathetic trunk, while the third and fourth right lumbar arteries pass deep to its medial border. In its upper part, it lies on the right crus of the Diaphragm, from which it is partially separated by the medial part of the right suprarenal gland and the right cœliac ganglion, and the right renal, suprarenal and phrenic arteries, which cross behind it.

On its *right side* the inferior vena cava is related to the right ureter—with which, however, it is not in immediate contact—the second part of the duodenum, the medial border of the right kidney and the right lobe of the liver.

On its *left side* it is related to the aorta, below, and to the right crus of the Diaphragm and the caudate lobe of the liver above.

Relations of the thoracic portion.—This part of the inferior vena cava is very short, and is situated partly inside and partly outside the pericardial sac. The *extrapericardial part* is separated from the right pleura and lung by the right phrenic nerve. The *intrapericardial part* is covered on the front and sides by the serous layer of the pericardium.

Peculiarities.—Numerous anomalies of the inferior vena cava have been recorded and are attributable to arrests or errors in the complicated series of developmental changes which result in its formation. The vessel is sometimes represented, below the level of the renal veins, by two, more or less symmetrical veins. The condition is often associated with failure of the cross anastomosis connecting the two common iliac veins and is due to persistence on the left side of the body of one of the longitudinal channels (usually supra- or subcardinal) which normally disappear in early fœtal life (p. 157). In complete transposition of the viscera, the inferior vena cava lies to the left side of the aorta.

Applied Anatomy.—Thrombosis of the inferior vena cava is due to much the same causes as thrombosis of the superior vena cava. It usually causes œdema of the legs and back, without ascites ; if the renal veins are involved, blood and albumin will often appear in the urine. An extensive collateral venous circulation is soon established by enlargement either of the superficial or of the deep veins, or of both. In the first case the epigastric, the circumflex iliac, the lateral thoracic, thoraco-epigastric (p. 832), the internal mammary, the posterior intercostals, the external pudendal and the lumbovertebral anastomotic veins effect the communication with the superior vena cava ; in the second, the deep anastomosis is made by the azygos and hemiazygos and the lumbar veins.*

* G. Blumer, in Osler and McCrae's *System of Medicine*, London, 1908, vol. iv.

Tributaries.—In addition to the two common iliac veins the inferior vena cava receives the following veins :

Lumbar.	Renal.	Inferior phrenic.
Right testicular or ovarian.	Right suprarenal.	Hepatic.

The **lumbar veins**, four in number on each side, collect the blood by dorsal tributaries from the muscles and skin of the loins, and by abdominal tributaries from the walls of the abdomen, where they communicate with the epigastric veins. At the vertebral column they receive veins from the vertebral plexuses, and they are connected with one another in this situation by the *ascending lumbar vein*—a longitudinal vessel placed in front of the roots of the transverse processes of the lumbar vertebræ. The *third* and *fourth lumbar veins* pass forwards on the sides of the bodies of the corresponding vertebræ and enter the posterior aspect of the inferior vena cava. Those of the left side pass behind the abdominal aorta and are longer than those of the right side. The *first* and *second lumbar veins* may end in the inferior vena cava or they may end in the ascending lumbar or lumbar azygos veins. As a rule, the first lumbar vein does not pass directly into the inferior vena cava. It may turn downwards to join the second and so open into it indirectly, but more frequently it ends in the ascending lumbar vein or passes forwards over the side of the body of the first lumbar vertebra and terminates in the lumbar azygos vein (p. 827). The second lumbar vein may join the inferior vena cava at or below the level of the renal veins. Sometimes it joins the third lumbar vein or it may terminate in the ascending lumbar vein. The first and second lumbar veins are frequently connected to each other, to the vessels of the opposite side, and to the right and left lumbar azygos veins by a plexiform network which lies on the bodies of the upper lumbar vertebræ.

The *ascending lumbar vein* is a longitudinal vessel which connects the common iliac, iliolumbar and lumbar veins. It is placed deeply under cover of the Psoas major and in front of the roots of the transverse processes of the lumbar vertebræ. At its upper end it joins the subcostal vein, and the trunk so formed turns forwards over the side of the body of the twelfth thoracic vertebra and, passing deep to the crus of the Diaphragm, ascends in the thorax as the azygos vein, on the right side, and as the inferior hemiazygos vein, on the left side. There is an angled bend on the vessel as it turns upwards, and it is usually joined at this point by a small vessel which springs from the back of the inferior vena cava (or from the left renal vein, on the left side). This little vessel represents the azygos line (p. 156), and has already been described as the *lumbar azygos vein*. Not infrequently the ascending lumbar vein ends in the first lumbar vein, which then turns forwards over the side of the first lumbar vertebra in company with the first lumbar artery and joins the lumbar azygos vein. In this case the subcostal vein joins the azygos vein (inferior hemiazygos vein, on the left side).

The **testicular veins** (spermatic veins) (fig. 738) emerge from the back of the testis, and receive tributaries from the epididymis ; they unite and form a convoluted plexus, called the *pampiniform plexus*, which constitutes the chief mass of the spermatic cord and ascends along the cord, in front of the vas deferens. Below the superficial inguinal ring (subcutaneous inguinal ring) the veins of the plexus unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the deep inguinal ring (abdominal inguinal ring), coalesce to form two veins, which run upwards in front of the Psoas major and the ureter, behind the peritoneum, lying one on each side of the testicular artery. These two veins join to form a single vessel, which on the right side opens into the inferior vena cava at an acute angle a little below the level of the renal veins ; on the left side it opens into the left renal vein at a right angle. The testicular veins are provided with valves.* The left vein passes behind the lower part of the descending colon and the lower margin

* Rivington has pointed out that valves are usually found at the orifices of both the right and left testicular veins. When, however, valves are not found at the opening of the left testicular vein into the left renal vein, they are generally present in the left renal vein within 6 mm. from the orifice of the testicular vein.—*Journal of Anatomy and Physiology*, vol. vii. p. 163.

of the pancreas and is crossed by the left colic vessels ; the right passes behind the terminal part of the ileum and the third part of the duodenum and is crossed by the root of the mesentery, the ileocolic and the right colic vessels.

Applied Anatomy. The testicular veins are very frequently varicose, constituting the condition known as *varicocele*. Varicocele almost invariably occurs on the left side, and this has been accounted for by the facts that the left testicular vein joins the left renal at a right angle ; that it is overlaid by the lower part of the descending colon, and that when this portion of the gut is full of fæcal matter, in cases of constipation, its weight impedes the return of the venous blood.

After the removal of a varicocele the venous return is subsequently carried out by the small veins of the vas deferens, of the Cremaster and those connecting with the scrotal tissues.

The **ovarian veins** in the female correspond with the testicular veins in the male ; each forms a plexus between the layers of the broad ligament near the ovary and uterine tube, and communicates with the uterine plexus. Two veins issue from this plexus and ascend across the external iliac artery, one lying on each side of the ovarian artery. Their further course and their mode of termination are the same as those of the testicular veins. Valves are occasionally found in the ovarian veins. Like the uterine veins, they become much enlarged during pregnancy.

The **renal veins**, which are of large size, are placed in front of the renal arteries, and they open into the inferior vena cava almost at right angles. The *left* is thrice the length of the right (7·5 cm. to 2·5 cm.), and crosses the posterior abdominal wall, lying behind the splenic vein and the body of the pancreas. Near its termination it passes in front of the aorta, just below the origin of the superior mesenteric artery. The left testicular (or ovarian) vein enters it from below, and the left suprarenal vein, which generally receives one of the left phrenic veins, enters its upper border a little nearer the median plane. The left renal vein opens into the inferior vena cava at a slightly higher level than the right. The *right renal vein* lies behind the second part of the duodenum and, sometimes, the lateral part of the posterior aspect of the head of the pancreas.

Occasionally the left renal vein may be duplicated, and in these cases one vein passes behind the aorta to join the inferior vena cava—persistence of the renal collar (p. 157)—or the anterior vessel may be entirely absent. The latter condition represents persistence of the posterior limb of the renal collar combined with absence of the intersubcardinal anastomosis.

The **suprarenal veins** are two in number, one issuing from the hilum of each suprarenal gland. The right vein is very short and passes directly into the posterior aspect of the inferior vena cava ; the left runs downwards and medially, in front of or just lateral to the left cœliac ganglion, and passes behind the body of the pancreas to end in the left renal vein.

The **phrenic veins** (inferior phrenic veins) follow the course of the corresponding arteries on the Diaphragm ; the right ends in the inferior vena cava ; the left is often represented by two branches, one of which ends in the left renal or suprarenal vein, while the other passes in front of the œsophageal opening in the Diaphragm and joins the inferior vena cava.

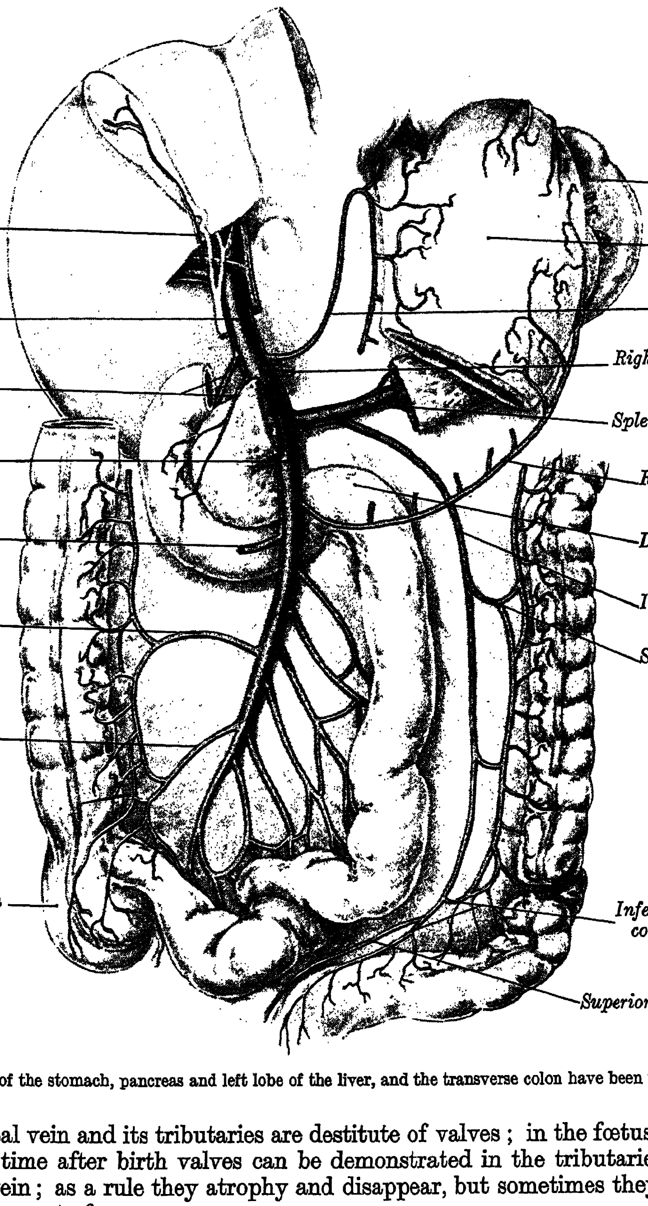
The **hepatic veins** drain the liver, and commence in the *intralobular veins*, which receive the blood from the sinusoids of the liver lobules. The intralobular veins open into the *sublobular veins*, and these in turn unite to form the hepatic veins, which open into the inferior vena cava as it lies in the groove on the posterior surface of the liver. The hepatic veins are arranged in two groups, upper and lower. The *upper group* usually consists of three large veins, right, left and middle, the last emerging from the caudate lobe ; those of the *lower group* vary in number ; they are of small size and come from the right and caudate lobes. The hepatic veins are in direct contact with the hepatic tissue and are destitute of valves.

The Portal System of Veins (fig. 791)

The portal system includes all the veins which drain the blood from the abdominal part of the digestive tube (with the exception of the lower part of the

rectum and anal canal) and from the spleen, pancreas, and gall-bladder. From these viscera the blood is conveyed to the liver by the *portal vein*. In the liver this vein ramifies like an artery and ends in capillary-like vessels termed sinusoids; from which the blood is conveyed to the inferior vena cava by the hepatic veins. The blood of the portal system therefore passes through two sets of minute vessels, viz. (*a*) the capillaries of the digestive tube, spleen, pancreas, and gall-bladder ; and (*b*) the sinusoids of the liver. In the adult

FIG. 791.—The portal vein and its tributaries. Semidiagrammatic.



Portions of the stomach, pancreas and left lobe of the liver, and the transverse colon have been removed.

the portal vein and its tributaries are destitute of valves ; in the fœtus and for a short time after birth valves can be demonstrated in the tributaries of the portal vein ; as a rule they atrophy and disappear, but sometimes they persist in a degenerate form.

The **portal vein** (figs. 791, 792) is about 8 cm. long, and is formed at the level of the second lumbar vertebra by the junction of the superior mesenteric and splenic veins, the union of these veins taking place in front of the inferior vena cava and behind the neck of the pancreas. It may be separated from the inferior vena cava by the upper part of the head of the pancreas, when that structure projects to the left. The vein inclines to the right as it passes upwards

behind the first part of the duodenum, the bile-duct and the gastroduodenal artery, and in front of the inferior vena cava; it then ascends in the right border of the lesser omentum in front of the aditus to the lesser sac (epiploic foramen) to reach the right extremity of the porta hepatis, where it divides into a right and a left branch, which accompany the corresponding branches of the hepatic artery into the substance of the liver. In the lesser omentum it is placed behind the bile duct and the hepatic artery, the former lying to the right of the latter; it is surrounded by the hepatic plexus of nerves, and is accompanied by numerous lymphatic vessels and some lymph glands. The *right branch* of the portal vein enters the right lobe of the liver, but before doing so generally receives the cystic vein. The *left branch*, longer but of smaller calibre than the right, gives branches to the caudate and quadrate lobes, and then enters the left lobe of the liver. As it does so, it is joined in front by the para-umbilical veins (p. 844) and by a fibrous cord, named the *ligamentum teres*, which represents the obliterated umbilical vein. It is connected to the inferior vena cava by a second fibrous cord, termed the *ligamentum venosum*, which ascends in a fissure on the posterior aspect of the liver.

The tributaries of the portal vein are:

1. Splenic.
2. Superior mesenteric.
3. Left gastric.
4. Right gastric.
5. Cystic.
6. Para-umbilical.

1. The **splenic vein** (fig. 791) is of large size, but is not tortuous like the artery; it commences by five or six branches which return the blood from the spleen. These unite to form a single vessel, which traverses the lienorenal ligament in company with the splenic artery and the tail of the pancreas. It then passes to the right with a downward inclination across the posterior abdominal wall, lying at a lower level than the splenic artery and grooving the upper part of the posterior surface of the pancreas, to which it is closely connected by numerous short tributaries from the gland. In its course it crosses the anterior surface of the left kidney and its hilum (or the lower pole of the left suprarenal gland), and it is separated from the left sympathetic trunk and crus of the Diaphragm by the left renal vessels, and from the abdominal aorta by the superior mesenteric artery and the left renal vein. It ends behind the neck of the pancreas where it unites at a right angle with the superior mesenteric vein, to form the portal vein.

Tributaries.—It receives the short gastric veins, the left gastro-epiploic vein, the pancreatic veins, and the inferior mesenteric vein.

(*a*) The **short gastric veins,** four or five in number, drain the fundus and left part of the greater curvature of the stomach, and pass between the two layers of the gastrosplenic ligament to end in the splenic vein or in one of its large tributaries.

(*b*) The **left gastro-epiploic vein** receives branches from both surfaces of the stomach and from the greater omentum; it runs from right to left along the greater curvature of the stomach and ends in the commencement of the splenic vein.

(*c*) The **pancreatic veins** are several small vessels which drain the body and tail of the pancreas.

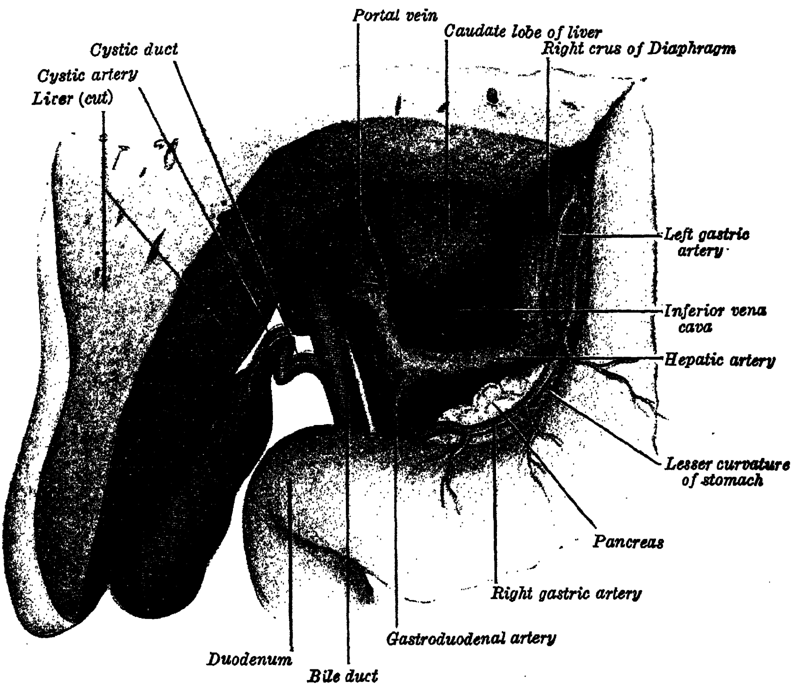
(*d*) The **inferior mesenteric vein** (fig. 791) returns blood from the rectum, and from the pelvic and descending parts of the colon. It begins in the rectum as the *superior rectal* (superior hæmorrhoidal) *vein*, which has its origin in the rectal plexus (p. 836), and through this plexus communicates with the middle and inferior rectal veins. The superior rectal vein leaves the true pelvis, crosses the left common iliac vessels with the superior rectal artery, and is continued upwards as the inferior mesenteric vein. This vein lies to the left of its artery and ascends behind the peritoneum and in front of the left Psoas major; its course is usually curved, convex to the left, and it may cross the testicular (or ovarian) vessels or lie to their medial side; it then passes above, or behind, the duodenojejunal flexure and opens into the splenic vein behind the body of the pancreas; sometimes it ends in the angle of union of the splenic and superior mesenteric veins.

If a superior duodenal or a paraduodenal fossa be present, the inferior mesenteric vein usually lies between the layers of the fold of peritoneum which forms the anterior wall of the fossa (fig. 1165).

Tributaries.—The inferior mesenteric vein receives the inferior left colic veins from the pelvic colon, and the superior left colic vein from the descending colon and left colic flexure.

2. The **superior mesenteric vein** (fig. 791) returns the blood from the small intestine, from the cæcum, and from the ascending and transverse portions of the colon. It begins in the right iliac fossa by the union of the veins which drain the terminal part of the ileum, the cæcum and vermiform appendix. It ascends between the two layers of the mesentery on the right side of the superior mesenteric artery, and in its upward course passes in front of the right ureter, the inferior vena cava, the third part of the duodenum, and the uncinate

FIG. 792.—Drawing of a dissection to show the relations of the hepatic artery, bile duct and portal vein in the lesser omentum.



process of the head of the pancreas. Behind the neck of the pancreas it unites with the splenic vein to form the portal vein.

Tributaries.—The superior mesenteric vein receives the veins which correspond to the branches of the superior mesenteric artery, viz. the jejunal, ileal, ileocolic, right colic, and middle colic veins; it is also joined by the right gastro-epiploic and the pancreaticoduodenal veins.

The **right gastro-epiploic vein** receives branches from the greater omentum and from the lower part of the stomach; it runs from left to right along the greater curvature of the stomach, between the anterior two layers of the greater omentum and joins the superior mesenteric vein below the neck of the pancreas.

The **pancreaticoduodenal veins** accompany their corresponding arteries; the lower one frequently joins the right gastro-epiploic vein; the upper one usually passes upwards and to the left behind the bile duct and terminates in the portal vein.

3. The **left gastric vein** derives tributaries from both surfaces of the stomach; it runs upwards along the lesser curvature of the stomach between the two layers of the lesser omentum, to the œsophageal opening of the stomach, where it receives some œsophageal veins. It then turns backwards and passes downwards and to the right behind the lesser sac of the peritoneum (omental

bursa), and ends in the portal vein at the upper border of the first part of the duodenum.

4. The **right gastric vein**, of small size, runs from left to right along the pyloric portion of the lesser curvature of the stomach between the two layers of the lesser omentum, and ends in the portal vein.

5. The **cystic vein** drains the blood from the gall-bladder; it accompanies the cystic duct, and usually ends in the right branch of the portal vein.

6. The **para-umbilical veins**, which establish an anastomosis between the veins of the anterior abdominal wall and the portal vein, are found in the course of the ligamentum teres of the liver and of the middle umbilical ligament. The best marked of these small veins is one which begins at the umbilicus and runs backwards and upwards in, or on the surface of, the ligamentum teres between the layers of the falciform ligament, to end in the left branch of the portal vein.

Applied Anatomy.—Obstruction to the portal vein may produce ascites, and this may arise from many causes, e.g. (1) the pressure of a tumour on the portal vein, such as cancer or hydatid cyst in the liver, enlarged lymph glands in the lesser omentum, or cancer of the head of the pancreas; (2) from cirrhosis of the liver, when the radicles of the portal vein are pressed upon by the contracting fibrous tissue in the portal canals; (3) from valvular disease of the heart, and back pressure on the hepatic veins, and so on the whole of the circulation through the liver. In this condition the prognosis as regards life and freedom from ascites may be much improved by the establishment of a good collateral circulation between the portal and systemic veins. This is effected by communications between (*a*) the gastric veins, and the œsophageal veins which often project as a varicose bunch into the stomach, emptying themselves into the inferior hemiazygos vein; (*b*) the veins of the colon and duodenum, and the left renal vein; (*c*) the accessory portal system of Sappey, branches of which pass in the round and falciform ligaments (particularly the latter) to unite with the epigastric and internal mammary veins, and through the diaphragmatic veins with the azygos; a single large vein, shown to be a para-umbilical vein, may pass from the hilum of the liver by the round ligament to the umbilicus, producing there a bunch of prominent varicose veins known as the *caput Medusæ*; (*d*) the veins of Retzius, which connect the intestinal veins with the inferior vena cava and its retroperitoneal branches; (*e*) the superior, middle and inferior rectal; (*f*) very rarely the ductus venosus remains patent, affording a direct connexion between the portal vein and the inferior vena cava.

Thrombosis of the portal vein is a very serious event, and is most often due to pathological processes causing compression of the vessel or injury to its wall, such as tumours or inflammation about the pylorus or head of the pancreas, or to gall-stones, or cirrhosis of the liver.

THE LYMPHATIC SYSTEM

In most of the tissues of the body there exists a wide-meshed plexus of vessels which contain a clear, colourless fluid. This fluid is termed *lymph* and it is composed, for the most part, of blood plasma which has transuded through the walls of the blood capillaries into the minute tissue spaces and has there become mixed with the tissue juices. As the pressure in these tissue spaces rises, the fluid which they contain passes into a closed system of vessels, termed *lymph vessels*. These eventually discharge the lymph into the great veins at the root of the neck, but all, save the terminal vessels, are interrupted in some part of their course by small, solid masses of lymphoid tissue, termed *lymph glands*. The lymphatic system comprises not only all the lymph vessels and lymph glands which will be described in this section, but also certain masses of lymphoid tissue found mainly in the walls of the alimentary canal which will be described with the digestive system.

The **lymph vessels** are exceedingly delicate and their coats so transparent that the fluid they contain is readily seen through them. In contrast with the blood-capillaries, which can absorb only those substances which are soluble in water, the lymph vessels are able to take up substances which are insoluble in water.* They are constricted at intervals and so present a knotted or beaded appearance; these constrictions correspond to the attachments of valves in the interior of the vessels. The smallest lymph vessels form a meshwork which is found interspersed amongst the elements and blood-vessels of the

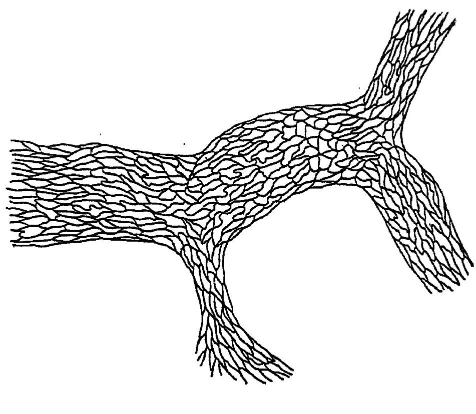
* P. T. Herring and F. G. Macnaughton, *The Lancet*, June 3rd, 1922.

tissues that they drain. The meshes of the network and the vessels themselves are much larger than those of the capillary plexuses. The walls of the vessels are complete and, in all probability, there are no direct communications between the lumen of a lymph vessel and the tissue spaces.

Lymph vessels have been found in nearly every tissue of the body which contains blood-vessels, but it would appear that they are more numerous in epithelial tissues. The lymph vessels of the small intestine are called *lacteals*; they differ from other lymph vessels only in regard to their function of fat absorption. After a meal containing this foodstuff, the lymph which they contain is milk-white in appearance and is termed *chyle*.

Lymph vessels are absent from the central nervous system, striped muscle and from non-vascular structures such as cartilage, nails, cuticle and hair. Their occurrence in bone is doubtful. Although no lymph vessels are found in the central nervous system, the blood-vessels entering the brain and spinal cord appear to be surrounded by perivascular spaces which are lined with the mesothelial cells of the pia mater. The cerebrospinal fluid circulates through these spaces and may therefore play the part of lymph. Woollard,* who used the vital method of injecting the subarachnoid space in cats, found that subsequently the dye was confined to the pia and arachnoid mater, and that these structures, together with the pial septa, were everywhere coloured. Further, the mesothelial cells of the pia mater contained granules of the dye and could be traced for considerable distances along the spaces in the sheaths of the blood-vessels entering the brain and spinal cord. These perivascular spaces may therefore be regarded as playing the part of lymph vessels.

FIG. 793.—A small lymph vessel, from the diaphragm of a rabbit. Silvered. ×65.



From the networks in the tissues small lymph vessels emerge and either pass to a neighbouring lymph gland or join some larger lymph trunk. The vessels are arranged in superficial and deep sets. The *superficial lymph vessels* lie immediately under the skin and may run independently or may accompany the superficial veins; in certain situations they join the deep vessels, but these connexions are by no means frequent. The superficial lymph vessels are especially numerous around the orifices where skin and mucous membrane become continuous, e.g., the mouth, the anus, the vagina, etc. Lymph vessels of a similar type are found in the submucous areolar tissue of the digestive, respiratory and urogenital systems and in the subserous tissue of the thoracic and abdominal walls. The *deep lymph vessels* always accompany vascular or neurovascular bundles; they are fewer in number but larger in calibre than the superficial vessels, although their mode of origin is probably similar.

The lymph vessels of any part exceed the veins in number, but they are much smaller in size. Their anastomoses—especially those of the larger trunks—are more numerous and are effected by vessels equal in diameter to those which they connect.

The lymph vessels unite with one another and ultimately form two main channels, named the *thoracic duct* and the *right lymphatic duct*, which open into the venous system at the root of the neck.

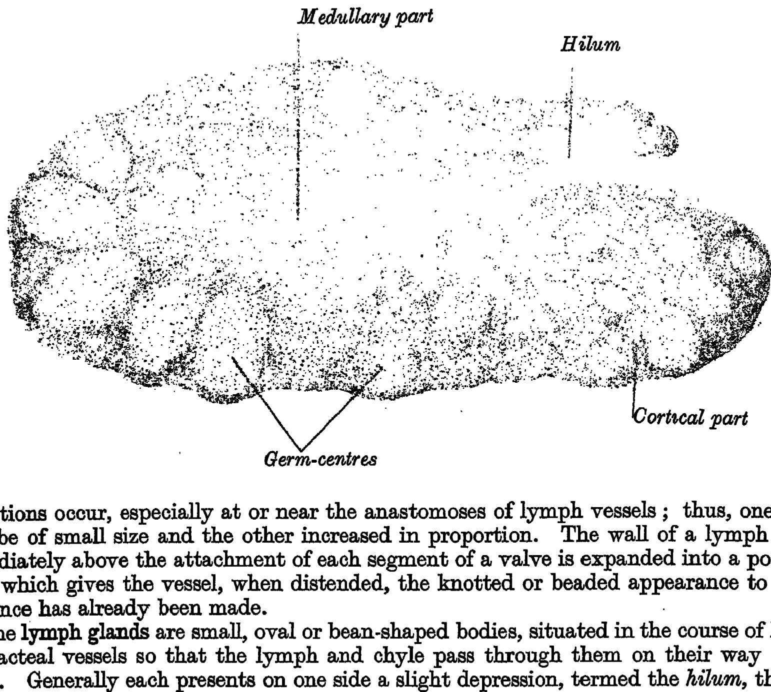
The structure of the lymph vessels.—The walls of the larger lymph vessels are composed of three coats. The *internal* coat is thin, transparent, and slightly elastic, and consists of a layer of elongated endothelial cells supported on an elastic membrane; the cells have wavy margins, by which contiguous cells are dovetailed into one another. The *middle* coat is composed of smooth muscular, and fine elastic fibres, disposed in a transverse direction. The *external* coat consists of connective tissue, intermixed with smooth muscular

* H. H. Woollard, *Journal of Anatomy*, vol. lviii.

fibres longitudinally or obliquely disposed; it forms a protective covering to the other coats and serves to connect the vessel with the neighbouring structures. In the smaller vessels there are no muscular or elastic fibres, and the wall consists only of a connective tissue coat lined by endothelium (fig. 793). The thoracic duct has a more complex structure than the other lymph vessels; it presents a distinct subendothelial layer, similar to that found in the arteries; in the middle coat there is, in addition to the muscular and elastic fibres, a layer of connective tissue with its fibres arranged longitudinally. Nutrient blood-vessels and many non-medullated nerves in the form of fine plexuses are distributed to the outer and middle coats of the larger lymph vessels.

In the lymph vessels the valves are placed at much shorter intervals than in the veins. They are most numerous near the lymph glands, and are found more frequently in the lymph vessels of the neck and upper limb than in those of the lower limb; they are wanting in the vessels composing the plexiform network in which the lymph vessels usually originate on the surface of the body. The valves are formed of thin layers of fibrous tissue covered on both surfaces by endothelium which presents the same arrangement as on the valves of veins (p. 666). They are semilunar in form, and are attached by their convex edges to the wall of the vessel, the concave edges being free and directed along the course of the lymph-current. Usually two valves, of equal size, are found opposite each other; but occasionally

FIG. 794.—A section through a lymph gland of a dog. Stained with hæmatoxylin and eosin. ×34.



exceptions occur, especially at or near the anastomoses of lymph vessels; thus, one valve may be of small size and the other increased in proportion. The wall of a lymph vessel immediately above the attachment of each segment of a valve is expanded into a pouch or sinus which gives the vessel, when distended, the knotted or beaded appearance to which reference has already been made.

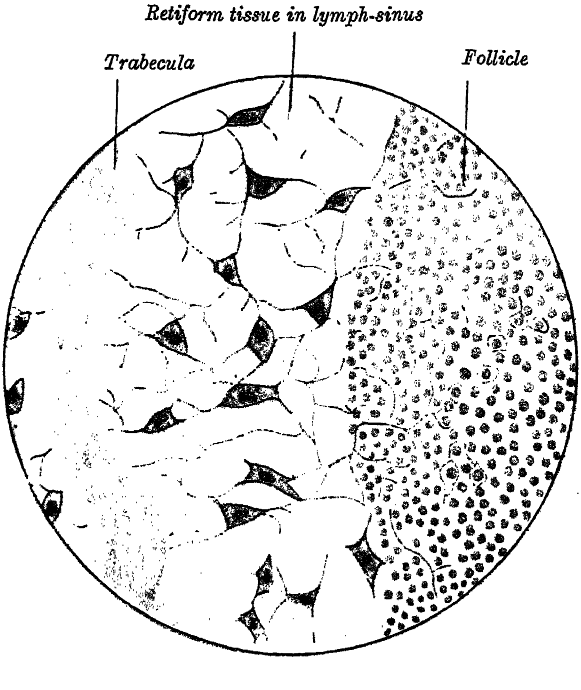
The **lymph glands** are small, oval or bean-shaped bodies, situated in the course of lymph and lacteal vessels so that the lymph and chyle pass through them on their way to the blood. Generally each presents on one side a slight depression, termed the *hilum*, through which the blood-vessels enter and leave the gland. The efferent lymph vessel also emerges from the gland at this spot, while the afferent vessels enter it at different parts of the periphery. On section (fig. 794), a lymph gland displays two different structures: an external, of lighter colour—the *cortical*; and an internal, darker—the *medullary*. The cortical structure does not form a complete investment, but is deficient at the hilum, where the medullary portion reaches the surface of the gland; so that the efferent lymph vessel is derived directly from the medullary structure, while the afferent vessels empty themselves into the cortical substance.

The **structure of the lymph glands** (figs. 794, 795). A lymph gland consists of (1) a fibrous envelope, or *capsule*, from which a framework of processes (*trabeculæ*) proceeds inwards, imperfectly dividing the gland into a number of freely communicating spaces; (2) a quantity of lymphoid tissue occupying these spaces without filling them completely; (3) a *lymph-path* or *lymph-sinus*, consisting of a large number of irregular, interconnecting spaces, which communicate with both the afferent and the efferent lymph vessels; and (4) a free supply of blood-vessels, which are supported in the trabeculæ. The nerves passing into the hilum are few in number and are chiefly distributed to the blood-vessels supplying the gland.

In man the *capsule* and *trabeculæ* are composed of fibro-areolar tissue with some plain muscular fibres, but in many of the lower animals they consist almost entirely of the latter.

The trabeculæ pass inwards towards the centre of the gland for about one-third or one-fourth of the distance between the circumference and the centre of the gland. In some animals they are sufficiently well marked to divide the peripheral or cortical portion of the gland into a number of compartments, but in man this arrangement is not obvious. The larger trabeculæ springing from the capsule break up into finer bands, and these interlace to form a meshwork in the central or medullary portion of the gland. In the *cortex* the gland-pulp or lymphoid tissue is arranged in imperfectly separated follicles or nodules, surrounded peripherally by the lymph-sinus, which separates them from the capsule and trabeculæ (fig. 795). In stained sections the central portions of the follicles appear clearer than the surrounding gland-pulp. Their cells are larger, frequently show karyokinetic figures and are not so densely packed together. In these areas, which are termed *germ-centres*, the cells are actively dividing. In the *medulla* the lymphoid tissue is arranged in irregular cords, separated from one another by the lymph-sinus and trabeculæ. These cords do not contain germ centres, but otherwise they show the same structure as the follicles, with which they are continuous at their peripheral ends.

FIG. 795.—Retiform and adenoid tissue, from a lymph gland. ×255.



The gland-pulp consists of ordinary lymphoid tissue (fig. 795), being made up of a delicate network of retiform tissue packed with lymphocytes. The network of the gland-pulp is continuous with that in the lymph-paths, but marked off from it by a closer reticulation; moreover, the fibres of the retiform tissue of the lymph-paths are continuous with those of the trabeculæ. The gland-pulp is traversed by a dense plexus of capillary blood-vessels.

The *afferent vessels*, as stated above, enter at different parts of the periphery of the gland, and after branching and forming a dense plexus in the substance of the capsule, open into the part of the lymph sinus immediately beneath the capsule. This *subcapsular lymph space* is everywhere in continuity with the lymph-sinuses of the cortical part. As the afferent vessels enter they lose all their coats except their endothelial lining, which is continuous with a layer of similar cells lining the lymph-paths. The *efferent vessel* commences from the lymph-sinuses of the medullary portion. The stream of lymph carried to the gland by the afferent vessels thus passes through the plexus in the capsule to the lymph-paths of the cortical portion, where it is exposed to the action of the gland-pulp; after flowing through these it enters the paths or sinuses of the medullary portion, and finally emerges from the hilum by means of the efferent vessel. The stream of lymph in its passage through the lymph sinuses is much retarded by the presence of the reticulum, hence morphological elements carried

in the lymph stream, either normal or morbid, are easily arrested and deposited in the sinuses. Many lymph corpuscles pass with the efferent lymph-stream to join the general blood-stream. The arteries of the gland enter at the hilum and go to the gland-pulp, there to break up into a capillary plexus, either directly or after running in the trabeculæ for a certain distance. The veins emerge from the gland at the hilum.

Applied Anatomy.—The lymph vessels and lymph glands draining any infected area of the body are very liable to become inflamed, resulting in acute or chronic lymphangitis and lymphadenitis. In acute cases the paths of the superficial lymph vessels are often marked out on the skin by painful, red lines leading to tender, swollen lymph glands, which may suppurate. Chronic lymphangitis, together with the blocking of numerous lymphatic vessels by the escaped ova of the minute parasitic worm *Microfilaris nocturna*, is the cause of elephantiasis, a condition common in the tropics and subtropics, and characterised by enormous enlargement and thickening of the skin of some part of the body, most frequently of the leg and scrotum. Tuberculous, syphilitic and cancerous enlargements of the lymph vessels and lymph glands are very commonly met with.

The present view is that cancer spreads more frequently by permeating the lymph vessels as a solid cell-growth, than by minute emboli. Operations for the removal of cancer are therefore planned to take away in one mass the cancer, the intervening lymph vessels, and the lymph glands.

The appearance of secondary malignant deposits or of secondary infection in parts of the body that seem not to be directly associated by any lymphatic connexion with the seat of the primary growth or infection has often been observed, and explained as due to 'retrograde transport' of cancer-cells or bacteria by a reversed flow of lymph. Weleminsky* however, believes that the explanation is to be found in the fact that when the infected lymph glands have grown to a certain size they no longer permit the normal flow of lymph through them, and that in these circumstances very delicate lymphatic connexions, whose existence normally remains unsuspected, develop to a surprising extent between groups of lymph glands that at first sight appear to be unconnected with one another. In this connexion the possibility of spread by the blood-stream should not be disregarded entirely. Recent work † has shown that lymph vessels in a pedicle skin graft survive in the graft and can replace vessels which have been destroyed.

The Thoracic Duct

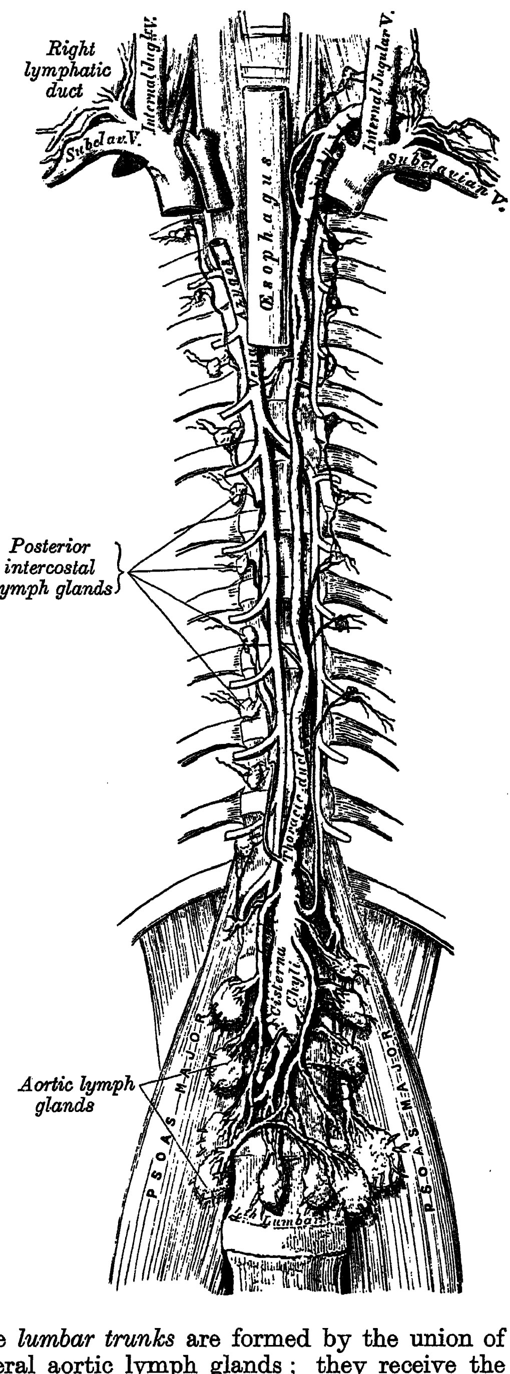
The **thoracic duct** (fig. 796) conveys the chyle and the greater part of the lymph into the blood. It is the common trunk of all the lymph vessels of the body, excepting those of the right side of the head, neck, and thoracic wall, the right upper limb, right lung, right side of the heart, and part of the convex surface of the liver. In the adult it varies in length from 38 cm. to 45 cm. and, including the cisterna chyli, extends from the second lumbar vertebra to the root of the neck. It begins at the upper end of the cisterna chyli (p. 849) near the lower border of the twelfth thoracic vertebra and enters the thorax through the aortic opening of the Diaphragm. It then ascends through the posterior mediastinum with the aorta on its left, and the azygos vein on its right side. In this part of its course the vertebral column and anterior longitudinal ligament, the right aortic intercostal arteries, and the terminal parts of the hemiazygos veins lie behind it. The Diaphragm and the œsophagus lie in front of it, but a recess of the right pleural cavity may intervene between the duct and the œsophagus. Opposite the fifth thoracic vertebra the thoracic duct inclines towards the left side, enters the superior mediastinum, and ascends to the thoracic inlet along the left edge of the œsophagus. After being crossed by the aortic arch, it lies behind the commencement of the left subclavian artery and in close contact with the mediastinal pleura of the left side. Passing into the neck it arches laterally at the level of the transverse process of the seventh cervical vertebra, the arch rising about 3 cm. or 4 cm. above the clavicle. In this part of its course the duct runs anterior to the vertebral artery and vein, the sympathetic trunk and the thyrocervical trunk or its branches. It also passes in front of the phrenic nerve and the medial border of the Scalenus anterior, but is separated from these two structures by the prevertebral fascia. In this part of its course it is placed behind the left common carotid artery, vagus nerve, and internal jugular vein. Finally, it

* *Berliner klin. Woch.*, 1905, No. 24, p. 743.

† J. H. Gray, *Journal of Anatomy*, vol. lxxii. part i.

descends in front of the first part of the left subclavian artery. It ends by opening into the angle of junction of the left subclavian vein with the left internal jugular vein, but it sometimes breaks up into a variable number of smaller vessels just prior to its termination. At its commencement the thoracic duct is about ·5 cm. in diameter, but it diminishes considerably in calibre in the middle of the thorax, and is again slightly dilated just before its termination. It is generally flexuous, and constricted at intervals so as to present a varicose appearance. Not infrequently it divides in the middle of its course into two vessels of unequal size which soon reunite, or into several branches which form a plexiform interlacement. It occasionally divides at its upper part into two branches, right and left; the left ending in the usual manner, while the right opens into the right subclavian vein, in connexion with the right lymphatic duct. The thoracic duct has several valves, and these tend to be placed in situations where the duct is exposed to pressure; at its termination it is provided with a pair, the free borders of which are turned towards the vein so as to prevent the passage of venous blood into the duct.

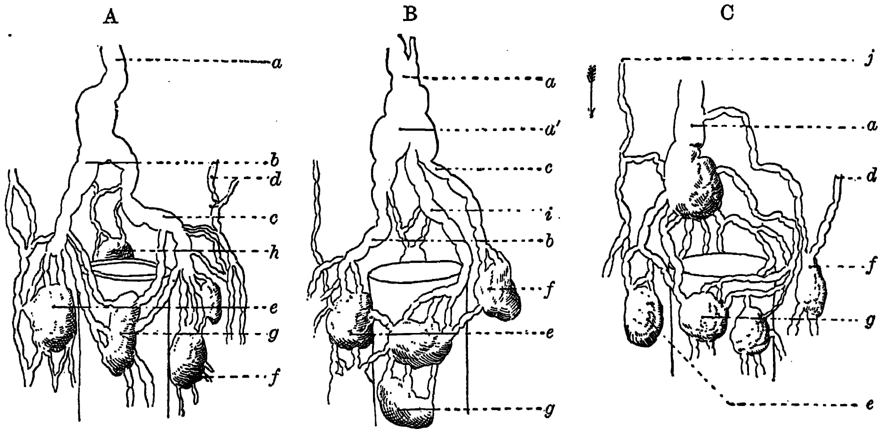
FIG. 796.—The thoracic and right lymphatic ducts.



The **cisterna chyli** (fig. 797) is a sac-like dilatation on the lymphatic pathway from the abdomen and lower limbs. It is 5 cm. to 7 cm. long and is situated in front of the bodies of the first and second lumbar vertebræ, immediately to the right of the abdominal aorta. The upper two lumbar arteries of the right side and the right lumbar azygos vein, when it is present, intervene between the cisterna chyli and the vertebral column. Anteriorly the cisterna chyli is covered by the medial edge of the right crus of the Diaphragm. It receives the right and left lumbar and the intestinal lymphatic trunks. The *lumbar trunks* are formed by the union of the efferent vessels from the lateral aortic lymph glands; they receive the lymph from the lower limbs, from the walls and viscera of the pelvis, from the kidneys and suprarenal glands, the testes (or ovaries), and the deep lymph vessels of the greater part of the abdominal wall. The *intestinal trunk* receives the lymph from the stomach, intestine, pancreas and spleen, and from the lower and anterior part of the liver.

Tributaries.—At its commencement the thoracic duct receives a descending trunk from the posterior intercostal lymph glands of the lower six or seven intercostal spaces, on each side. In the thorax the thoracic duct is joined on each side by a trunk which drains the upper lumbar lymph glands and pierces the crus of the Diaphragm. It also receives the efferents from the posterior mediastinal lymph glands and from the posterior intercostal lymph glands of

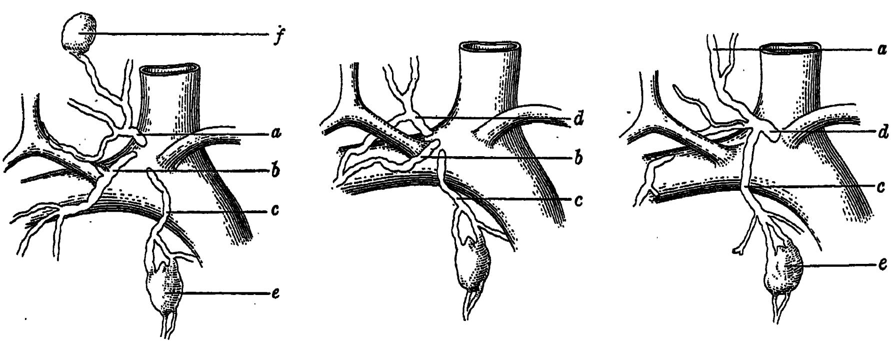
FIG. 797.—Modes of origin of the thoracic duct. (Poirier and Charpy.)



a. Thoracic duct. *a'*. Cisterna chyli. *b*. *c*. Efferent trunks from lateral aortic lymph glands. *d*. An efferent vessel which pierces the left crus of the Diaphragm. *e*. *f*. Lateral aortic lymph glands. *g*. Pre-aortic lymph glands. *h*. Retro-aortic lymph glands. *i*. Intestinal trunk. *j*. Descending branch from intercostal lymph vessels.

the upper six spaces of the left side. In the neck it is joined usually by the *left jugular trunk* from the left side of the head and neck, and the *left subclavian trunk* from the left upper limb, but these vessels may open independently into the internal jugular vein and the subclavian vein, respectively; sometimes it is joined by the *left bronchomediastinal trunk*, but this trunk usually opens independently into the junction of the left subclavian and internal jugular veins.

FIG. 798.—The terminal lymph trunks of the right side. (Poirier and Charpy.)



a. Jugular trunk. *b*. Subclavian trunk. *c*. Bronchomediastinal trunk. *d*. Right lymphatic duct. *e*. Lymph gland of internal mammary chain. *f*. Lymph gland of deep cervical chain.

The **right lymphatic duct** (figs. 796, 798), about 1 cm. in length, courses along the medial border of the Scalenus anterior at the root of the neck, and ends by opening into the angle of junction of the right subclavian and right internal jugular veins. Its orifice is guarded by two semilunar valves, which prevent the passage of venous blood into the duct.

Tributaries.—The right lymphatic duct receives the lymph from the right side of the head and neck through the *right jugular trunk*; from the right upper limb through the *right subclavian trunk*; from the right side of the thorax, right lung, right side of the heart, and part of the convex surface of the liver,

through the *right bronchomediastinal trunk*. These three trunks frequently open separately in the angle of union of the two veins (fig. 798).

Applied Anatomy.—Blockage of the thoracic duct by mature specimens of the minute parasitic worm *Microfilaria nocturna* gives rise to stasis of the chyle, and to its passage in various abnormal directions on its course past the obstruction. The neighbouring abdominal, renal, and pelvic lymph vessels become enlarged, varicose, and tortuous, and chyle may make its way into the urine (chyluria), the tunica vaginalis (chylocele), the abdominal cavity (chylous ascites) or the pleural cavity (chylous pleural effusion), in consequence of rupture of some of these distended lymph vessels.

The thoracic duct has been wounded in removing tuberculous glands from the neck. When this happens the duct should be ligatured in the same way as a vein. The chyle then appears to find its way into the veins by anastomosing channels.

THE LYMPHATIC DRAINAGE OF THE HEAD AND NECK *

The lymph glands of the head and neck comprise a terminal group and a number of intermediary, outlying groups. The terminal group is closely associated with the carotid sheath and is named the *deep cervical group*. All the lymph vessels of the head and neck drain into this group, either directly from the tissues themselves, or indirectly after passing through one of the outlying groups. The efferents of the deep cervical lymph glands form the *jugular trunk*, which, on the right side, may end in the junction of the internal jugular and subclavian veins or may join the right lymphatic duct; on the left side, it usually enters the thoracic duct, although it may join either the internal jugular or the subclavian vein.

THE DEEP CERVICAL LYMPH GLANDS

The deep cervical lymph glands are found lying along the carotid sheath from the base of the skull to the root of the neck. They may be subdivided into (1) a superior and (2) an inferior group, both of which receive *afferents* direct from the tissues themselves as well as from the outlying, intermediary groups.

(1) The **superior deep cervical lymph glands** lie in close relationship with the upper part of the internal jugular vein. Most of them are hidden by the sternomastoid, but a few are found extending beyond the borders of the muscle. One group, which comprises one large and several small glands, is placed in the triangular area bounded by the posterior belly of the digastric, the common facial vein, and the internal jugular vein, and is termed the *jugulodigastric group*; it is associated particularly with the lymph drainage of the tongue.

Efferents from the upper deep cervical lymph glands pass to the lower deep cervical group as well as to the jugular trunk.

(2) The **inferior deep cervical lymph glands** are situated under cover of the lower part of the sternomastoid, and extend also into the subclavian triangle, where they are closely related to the brachial plexus and the subclavian vessels. One gland of this group lies on, or just above the intermediate tendon of the omohyoid muscle; it is called the jugulo-omohyoid gland (Jamieson and Dobson) † and is concerned especially with the drainage of the tongue (p. 856). The efferents from the lower deep cervical lymph glands join the jugular trunk.

From the point of view of their lymphatic drainage the tissues of the head and neck can conveniently be considered in two groups, viz.: (*a*) The superficial tissues and (*b*) the deeper structures, including the viscera.

* In this and the following sections only the larger and more constant groups of lymph glands are included. For a detailed description and references to the literature, the reader is referred to *Anatomie des Lymphatiques de l'homme*, by H. Rouvière. Masson et Cie. Paris, 1932.

† J. K. Jamieson and J. F. Dobson, "The lymphatics of the tongue," *British Journal of Surgery*, vol. viii. No. 29, 1920.

A. Lymphatic Drainage of the Superficial Tissues of the Head and Neck (fig. 800).

Most of the superficial tissues are drained by vessels which go first to outlying groups of glands, and the efferents from these glands pass to the deep cervical lymph glands. Some of the lymph, however, may pass directly to the deep cervical glands.

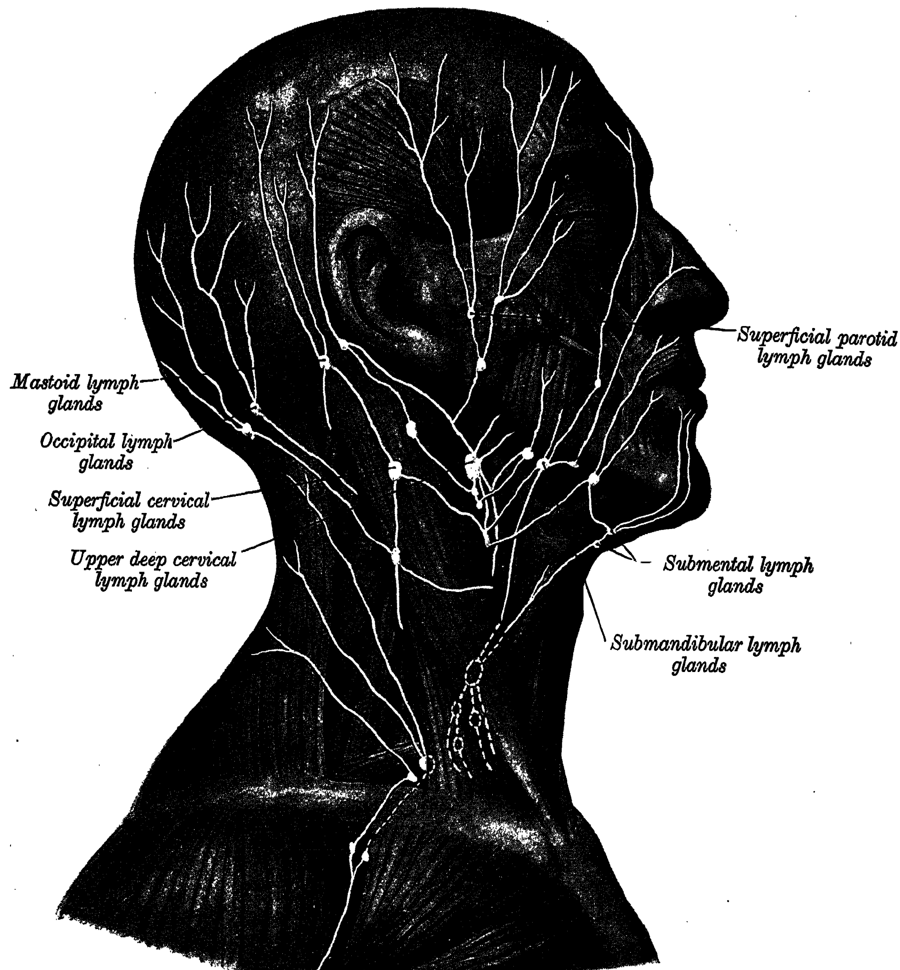


Fig. 799.—The superficial lymph glands and lymph vessels of the head and neck.

The outlying groups concerned in the drainage of the superficial tissues are:

In the head.	*In the neck.*
Occipital.	Submandibular.
Mastoid.	Submental.
Parotid.	Anterior cervical.
Facial.	Superficial cervical.

1. **Lymphatic drainage of the scalp and ear.**—(i) The lymph vessels from the frontal region just above the root of the nose drain into the submandibular group of glands (fig. 799) and will be considered with the lymphatics of the face.

(ii) The vessels from the rest of the forehead, from the temporal region of the scalp, and from the upper half of the lateral surface of the auricle and the anterior wall of the external auditory meatus drain into the *superficial parotid*

lymph glands, which lie immediately in front of the tragus, on, or deep to, the fascial investment of the parotid gland. These glands receive also the lateral lymph vessels from the eyelids and those from the skin over the zygomatic bone. Their efferent vessels pass to the upper deep cervical lymph glands.

(iii) A strip of the scalp above the auricle, the upper half of the cranial surface and margin of the auricle, and the posterior wall of the external auditory meatus are drained by vessels which pass, some to the upper deep cervical glands and others to the mastoid group.

The *mastoid lymph glands* (fig. 799) are placed superficial to the mastoid insertion of the Sternomastoid muscle, and deep to the Auricularis posterior. Their efferents pass to the upper deep cervical glands.

(iv) The lobule of the auricle, the floor of the external auditory meatus, and the skin over the angle of the jaw and the lower part of the parotid region are drained by vessels which may pass to the superficial cervical group of glands or to the upper deep cervical group. The *superficial cervical glands* are placed along the external jugular vein superficial to the Sternomastoid. Some of the efferents from this group pass round the anterior border of the Sternomastoid to reach the upper deep cervical glands; others follow the external jugular vein and join the lower deep cervical glands in the subclavian triangle.

(v) The occipital region of the scalp is drained partly by vessels which pass to the occipital group of glands, and partly by a trunk which descends along the posterior border of the Sternomastoid to end in the lower deep cervical glands. The *occipital lymph glands* are placed in the upper angle of the posterior triangle, superficial to the attachment of the Trapezius to the occipital bone.

2. **Lymphatic drainage of the face.**—(i) The lymph vessels draining the eyelids and conjunctiva commence in a superficial plexus beneath the skin and in a deep plexus in front of and behind the tarsi; these plexuses communicate with one another and medial and lateral sets of vessels arise from them. The lymph vessels of the lateral set drain the whole thickness of the upper lid with the exception of the skin over its medial part; they also drain the whole thickness of the lateral half of the lower lid and all the ocular conjunctiva. They pass laterally from the lateral commissure to end in the superficial parotid glands (p. 852) and also in the *deep parotid lymph glands*, which are imbedded in the substance of the parotid salivary gland. The deep parotid glands receive vessels also from the middle ear (p. 855). The lymph vessels of the medial set drain the skin over the medial part of the upper eyelid, the whole thickness of the medial half of the lower lid, and the caruncula lacrimalis. Following the course of the anterior facial vein they end in the submandibular group of glands.

The *submandibular lymph glands* (submaxillary glands) (figs. 799, 801) are placed beneath the deep cervical fascia in the submandibular triangle. They are usually three in number, one at the anterior end of the submandibular salivary gland, and one in front of, and another behind the facial artery where it reaches the mandible. Additional glands of this group are often found imbedded in the submandibular salivary gland or on its deep surface. The submandibular lymph glands receive afferents from a wide area, including vessels from the submental, facial, and lingual groups of glands; their efferents pass to both the upper and lower deep cervical glands.

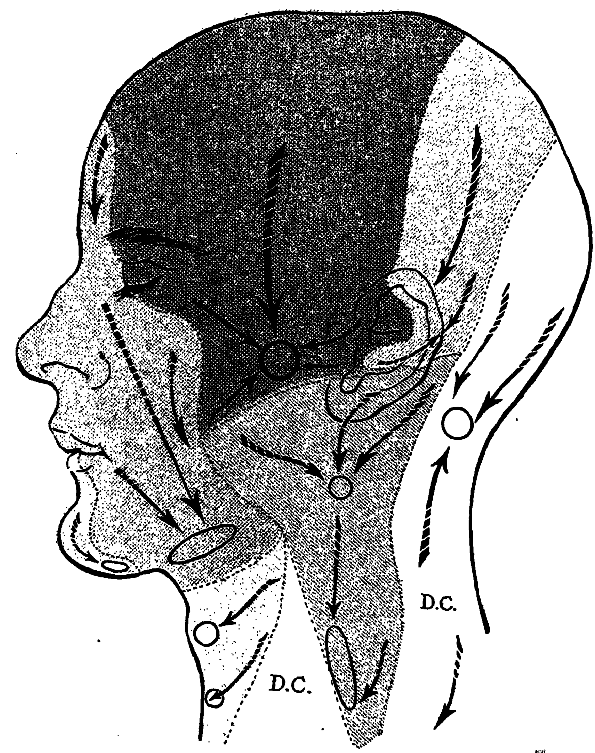
(ii) The external nose, cheek and upper lip, and the lateral part of the lower lip send their lymph to the submandibular glands. These vessels may have along their course a few *facial lymph glands* lying in relation to the anterior facial vein. The mucous membrane covering the oral surfaces of the lips and cheeks is drained by vessels which end also in the submandibular glands. The lymph from the lateral part of the cheek drains into the parotid group of lymph glands, whilst that from the skin over the root of the nose and the central part of the forehead just above this drains partly into the parotid glands, and partly, along the facial lymphatics, into the submandibular glands.

(iii) The central part of the lower lip, together with the floor of the mouth and the tip of the tongue, is drained by vessels which pass to the submental group of glands. The *submental lymph glands* are placed on the Mylohyoid muscle between the anterior bellies of the two Digastric muscles (fig. 801). They receive afferents from both sides of the median plane, some of the vessels

decussating over the symphysis of the mandible; their efferents pass to the submandibular and jugulo-omohyoid lymph glands.

3. **Lymphatic drainage of the neck.**—Many of the vessels draining the superficial tissues of the neck pass round the borders of the Sternomastoid to either the upper or the lower deep cervical glands. Some, however, pass from the region over the upper part of the Sternomastoid muscle and the posterior triangle of the neck to the superficial cervical and occipital lymph glands. The lymph from the upper part of the anterior triangle of the neck is drained into the submandibular and submental lymph glands, whilst the vessels from the skin of the anterior part of the neck below the hyoid bone pass to the *anterior*

Fig. 800.—The areas of lymphatic drainage of the superficial tissues of the head and neck.



cervical lymph glands, which are associated with the anterior jugular veins. The efferents from this group pass to the deep cervical glands of both sides of the neck; they also pass to the infrahyoid, prelaryngeal, and pretracheal glands (p. 855). One of the anterior cervical lymph glands often occupies the suprasternal space (p. 537).

B. Lymphatic Drainage of the Deeper Tissues of the Head and Neck.

The deeper tissues of the head and neck are drained by vessels which pass to the deep cervical glands either directly, or indirectly after passing through one of the outlying groups. In addition to the outlying groups which have been considered already, the following groups also are concerned with the drainage of the deeper tissues, viz.:

The retropharyngeal lymph glands.
The paratracheal lymph glands.
The lingual lymph glands.
The infrahyoid, prelaryngeal and pretracheal lymph glands.

The retropharyngeal lymph glands comprise a median and two lateral groups, the former near the median plane, and the latter in front of the lateral mass of the atlas along the lateral border of the Longus capitis muscle. The glands all lie in the interval between the fascia covering the pharynx and the prevertebral fascia. Their efferents pass to the upper deep cervical lymph glands.

The paratracheal lymph glands on each side are situated lateral to the trachea and œsophagus, along the course of the recurrent laryngeal nerve. Efferents from this group pass to the deep cervical lymph glands.

The infrahyoid, prelaryngeal and pretracheal lymph glands lie deep to the investing layer of the deep cervical fascia. They receive some of their afferents from the anterior cerv cal glands (p. 854) and their efferents join the deep cervical groups. The glands of the infrahyoid group are placed on the front of the thyrohyoid membrane; those of the prelaryngeal group lie on the cricovocal membrane; the pretracheal glands lie in front of the trachea in close relation with the inferior thyroid veins.

The lingual lymph glands are small and inconstant. They are found on the Hyoglossus muscle and between the two Genioglossi.

1. **The lymphatic drainage of the nasal cavity, nasopharynx and middle ear.**—The lymphatics of the nasal cavity can be injected from the subarachnoid space, through communications which exist along the course of the olfactory nerves. The lymph vessels from the anterior part of the nose pass superficially to join those draining the skin covering the nose and end in the submandibular lymph glands. The remainder of the nasal cavity, the paranasal sinuses, the nasopharynx, and the pharyngeal end of the pharyngotympanic tube are drained by vessels which pass to the upper deep cervical lymph glands, either directly or after traversing the retropharyngeal glands. It is probable that the posterior part of the floor of the nose is drained by vessels which enter the parotid group of lymph glands.

The lymph vessels of the mucous lining of the tympanum and mastoid antrum pass to the parotid or upper deep cervical lymph glands; those from the tympanic end of the pharyngotympanic tube probably end in the deep cervical glands.

2. **The lymphatic drainage of the larynx, trachea, and thyroid gland.**—The lymph vessels of the larynx comprise upper and lower groups; on the lateral wall the two systems are distinct one from another, the line of division being the vocal fold; the two systems anastomose on the posterior wall of the larynx. The vessels of the upper set pierce the thyrohyoid membrane, and, accompanying the superior laryngeal vessels, end in the upper deep cervical glands. The vessels of the lower set either pass between the cricoid cartilage and the first tracheal ring to go directly to the lower deep cervical glands, or, piercing the cricovocal membrane, pass to the pretracheal and prelaryngeal groups before reaching the deep cervical glands.

The cervical part of the trachea is drained by vessels which pass to the pretracheal and paratracheal lymph glands, or directly to the glands of the lower deep cervical group.

The lymph vessels of the thyroid gland accompany the veins. Vessels of the upper set pass to the deep cervical glands; those of the lower set to the pretracheal and paratracheal glands. Some of the vessels may run down into the superior mediastinum.

3. **The lymphatic drainage of the mouth, teeth, tonsil and tongue.**—(i) The *mouth.*—The vessels of the gums end in the submandibular lymph glands; those of the hard palate are continuous in front with those of the upper gum, but run backwards to pierce the superior constrictor muscle, and end in the upper deep cervical and retropharyngeal lymph glands; those of the soft palate pass backwards and laterally and end partly in the retropharyngeal, and partly in the upper deep cervical lymph glands. The vessels of the anterior part of the floor of the mouth go to the inferior lymph glands of the upper deep cervical group, either directly or indirectly through the submental lymph glands; the vessels from the rest of the floor of the mouth pass to the submandibular and upper deep cervical lymph glands.

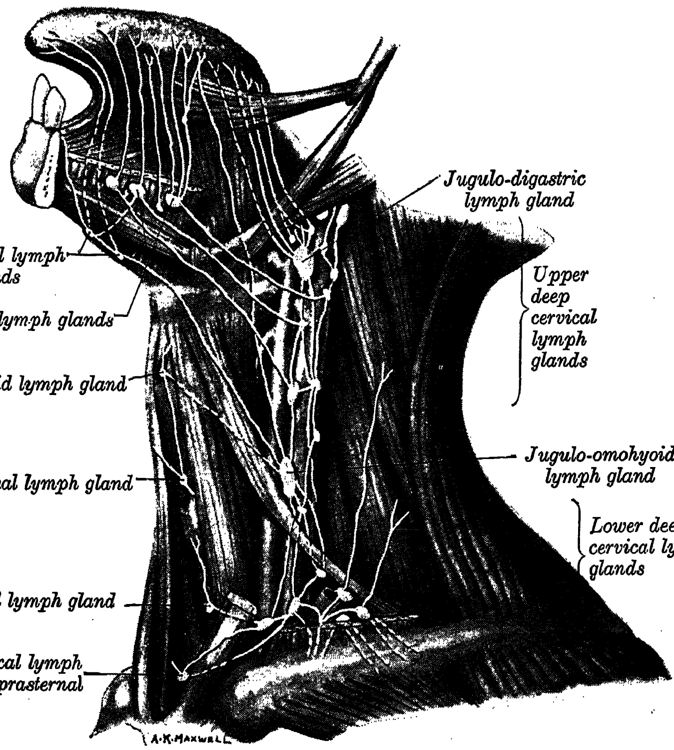
(ii) The *teeth.*—Lymph vessels were demonstrated in the pulp of the teeth

by Schweitzer * in 1907, and his observations have been confirmed by Dewey and Noyes.† They pass to the submandibular and deep cervical lymph glands.

(iii) The *tonsil*.—The lymph vessels of the tonsil, usually three to five in number, pierce the buccopharyngeal fascia and the superior constrictor muscle and pass between the stylohyoid and the internal jugular vein to reach the upper deep cervical lymph glands. Most of them end in the jugulodigastric lymph gland ; occasionally one or two additional vessels run to small lymph glands on the lateral side of the internal jugular vein, under cover of the sternomastoid.

(iv) The *tongue* (figs. 801, 802).‡—The lymphatic plexus in the mucous membrane of the tongue is continuous with the intramuscular plexus. The part of the tongue in front of the papillæ vallatæ is drained into marginal and

FIG. 801.—The lymphatic drainage of the tongue. (After Jamieson and Dobson.)



Note.—The removal of the Sternomastoid muscle has exposed the whole chain of deep cervical lymph glands.

central lymph vessels. The part of the tongue behind the papillæ vallatæ drains into a set of dorsal lymph vessels.

1. *Marginal vessels*.—The lymph vessels from the tip of the tongue, and region of the frenulum, descend under the mucous membrane and end in widely distributed lymph glands.

(*a*) Vessels pierce the origin of the mylohyoid in contact with the periosteum of the mandible ; one or two of these vessels enter the submental lymph glands, and one descends over the hyoid bone to the jugulo-omohyoid lymph gland. (It should be noted (1) that vessels arising in the plexus on one side of the tongue may cross under the frenulum and end in the lymph glands of the opposite side, and (2) that the efferent vessels of the submental lymph glands, which are placed in or near the median plane, pass impartially to either side.)

* *Archiv für Mikrosk. Anat. u. Entwickl.*, 1907 and 1909.

† *Dental Cosmos*, vol. lix. No. 4.

‡ This description of the lymphatic vessels of the tongue is based on the researches of Jamieson and Dobson (*loc. cit.* p. 851).

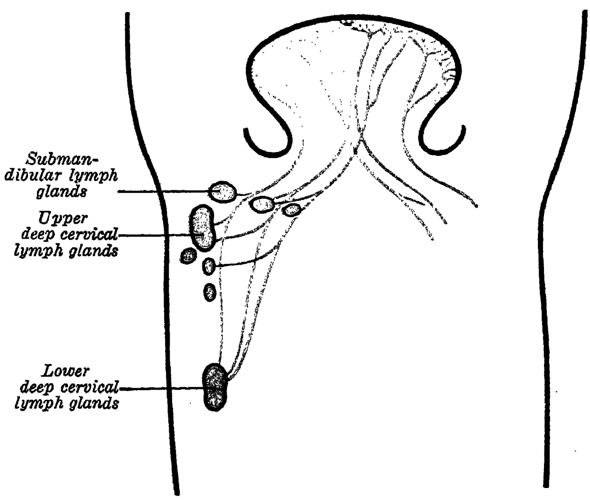
(*b*) Some vessels pierce the origin of the mylohyoid, and enter the anterior or the middle submandibular lymph gland.

(*c*) Some vessels pass deeply under the sublingual salivary gland and, accompanying the ranine vein, end in the jugulo-digastric lymph glands. One vessel often descends over or deep to the central tendon of the Digastric to reach the jugulo-omohyoid lymph gland.

Some of the lymph vessels from the lateral margin of the tongue pass over the sublingual salivary gland, pierce the Mylohyoid, and end in the submandibular lymph glands ; others pass under the salivary gland and end in the jugulo-digastric or jugulo-omohyoid glands.

The vessels from the posterior part of the margin of the tongue make their way through the pharyngeal wall to the jugulo-digastric lymph glands.

FIG. 802.—A diagram to show the course of the central lymph vessels of the tongue to the lymph glands on both sides of the neck. (Jamieson and Dobson.) *British Journal of Surgery*, vol. viii. 1920.



2. *Central vessels.*—There is no clear line of demarcation between areas on the surface of the tongue draining into the marginal or into the central vessels. The central lymph vessels descend in the median plane between the Genioglossi. Some turn laterally through the muscles, but the majority appear between their free borders and diverge to the right or left, i.e. the vessels from one side of the tongue may run to the lymph glands of the opposite side (fig. 802). They follow the lingual blood-vessels, and end in the deep cervical lymph glands, especially in the jugulo-digastric and jugulo-omohyoid glands. Some pierce the Mylohyoid and enter the submandibular lymph glands.

3. *Dorsal vessels.*—The vessels draining the area of the papillæ vallatæ, and the part of the tongue behind these papillæ, run downwards and backwards—those near the median plane may divide and run to both sides. They turn laterally to join the marginal vessels, and all pierce the pharyngeal wall, passing in front of or behind the external carotid artery, to reach the jugulo-digastric and jugulo-omohyoid lymph glands, or the glands between them. One vessel may descend behind the hyoid bone, perforate the thyrohyoid membrane, and end in the jugulo-omohyoid lymph gland.

4. **The lymphatic drainage of the pharynx and œsophagus.**—The collecting vessels from the pharynx and œsophagus pass to the deep cervical lymph glands either directly, or indirectly through the retropharyngeal or paratracheal glands. From the region of the epiglottis the lymph vessels run to the infrahyoid lymph glands.

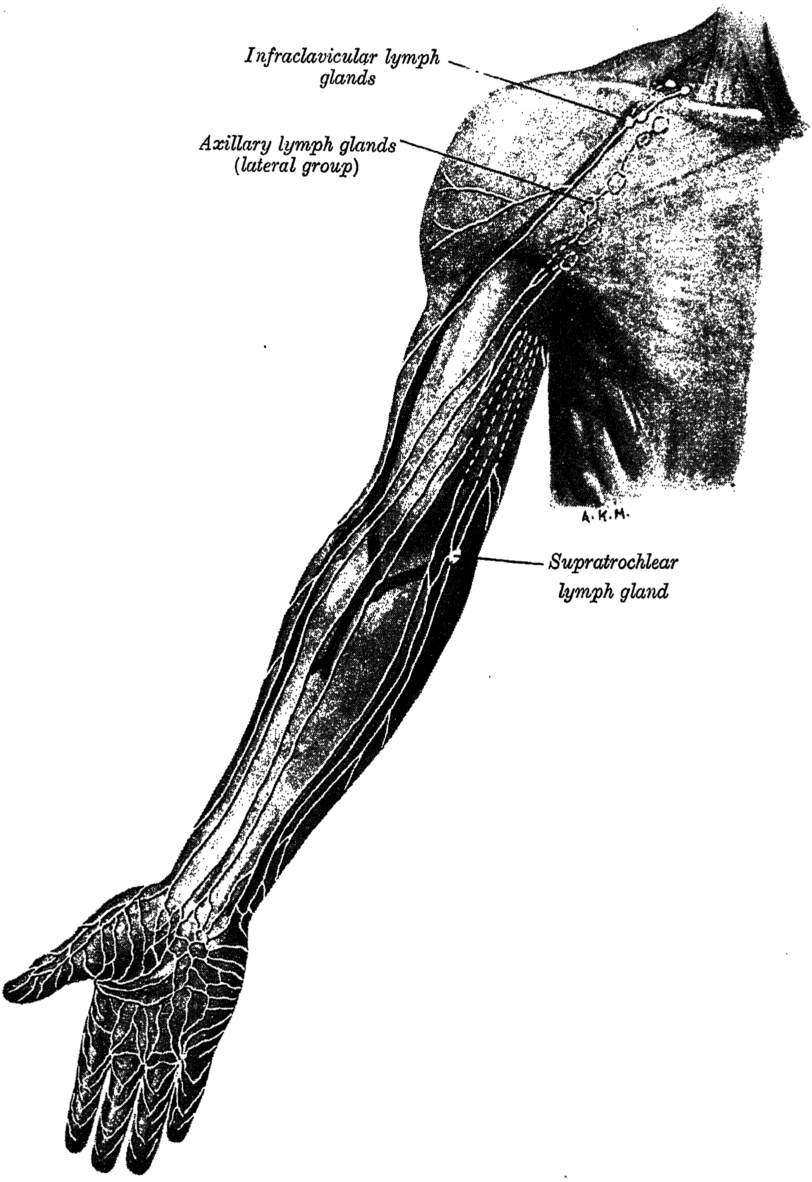
THE LYMPHATIC DRAINAGE OF THE UPPER LIMB

All the lymph vessels of the upper limb drain into a terminal group of lymph glands situated in the axilla, either directly from the tissues, or indirectly after passing through an outlying group of glands. The lymph vessels comprise deep and superficial sets. The deep vessels follow the principal vascular and neurovascular bundles, while the superficial vessels, except in the hand and on the back of the forearm, accompany the superficial veins more or less closely.

The axillary lymph glands (fig. 804), which are the terminal group for the whole of the upper limb, are of large size ; they vary from twenty to thirty in number, and may be divided into five groups, which are not sharply demarcated from one another :

1. A *lateral group* (fig. 803) of from four to six lymph glands lies medial to, and behind, the axillary vein ; the afferents of this group drain the whole

FIG. 803.—The lymphatic drainage of the superficial tissues of the upper limb. Anterior aspect. Semi-diagrammatic.



limb with the exception of that portion whose lymph vessels accompany the cephalic vein. The efferent vessels pass partly to the central and apical groups of axillary lymph glands, and partly to the lower deep cervical lymph glands.

2. An *anterior* or *pectoral group* of four or five lymph glands lies along the lower border of the Pectoralis minor, in relation with the lateral thoracic vessels.

Its afferents drain the skin and muscles of the anterior and lateral walls of the body, above the level of the umbilicus, and the central and lateral parts of the mammary gland (p. 861); its efferents pass partly to the central, and partly to the apical groups of axillary lymph glands.

3. A *posterior* or *subscapular group* of six or seven lymph glands is placed along the lower margin of the posterior wall of the axilla in the course of the subscapular vessels. The afferents of this group drain the skin and muscles of the lower part of the back of the neck and of the dorsal aspect of the trunk, as low down as the iliac crest; their efferents pass to the apical and to the central group of axillary lymph glands.

4. A *central group* of three or four large lymph glands is imbedded in the fat near the base of the axilla. It has no special area of drainage, but it receives afferents from all the preceding groups of axillary lymph glands: its efferents pass to the apical group.

5. An *apical group* of six to twelve lymph glands is situated partly posterior to the upper portion of the Pectoralis minor and partly above the upper border of this muscle, and extends upwards into the apex of the axilla along the medial side of the axillary vein. The only direct territorial afferents of this group are those which accompany the cephalic vein and one or two which drain the upper and peripheral part of the mammary gland, but it receives the efferents of all the other axillary lymph glands. The efferent vessels of this group unite to form the *subclavian trunk*, which opens either directly into the junction of the internal jugular and subclavian veins or into the jugular lymphatic trunk; on the left side it may end in the thoracic duct. A few efferents from the apical group usually pass to the lower deep cervical lymph glands.

The outlying groups of lymph glands in the upper limb are few in number. They comprise (1) the supratrochlear group, (2) the infraclavicular group (which are both interposed on the path of the superficial vessels), and (3) a few isolated lymph glands which are occasionally present along the course of the principal blood-vessels of the arm and forearm.

1. The *supratrochlear lymph glands*, one or two in number, lie on the deep fascia above the medial epicondyle of the humerus on the medial side of the basilic vein. Their efferents accompany the basilic vein and join the deep lymph vessels.

2. The *infraclavicular lymph glands*, one or two in number, are found beside the cephalic vein, between the Pectoralis major and the Deltoid, immediately below the clavicle. Their efferents pass through the clavipectoral fascia to reach the apical group of the axillary glands, or, more rarely, they may pass across the clavicle to reach the lower deep cervical group.

3. Isolated lymph glands, small in size, are sometimes found in the forearm along the radial, ulnar and interosseous vessels, in the cubital fossa near the bifurcation of the brachial artery, and in the arm along the medial side of the brachial vessels.

The lymphatic drainage of the superficial tissues of the upper limb.—The superficial lymph vessels begin in the lymphatic plexuses in the skin.

In the hand, the meshes of the plexus are much finer on the palmar than on the dorsal surface. The digital plexuses are drained by vessels which run along the borders of the digits to reach the web, where they receive vessels from the distal part of the palm and then pass backwards to reach the dorsal surface of the hand (figs. 803, 805). The rest of the palm is drained by vessels which pass proximally towards the wrist, medially to join vessels along the ulnar border of the hand, and laterally to join those on the thumb. Several collecting vessels from the central part of the palmar plexus unite to form a trunk which winds round the metacarpal bone of the index finger to join the dorsal vessels from the same finger and from the thumb.

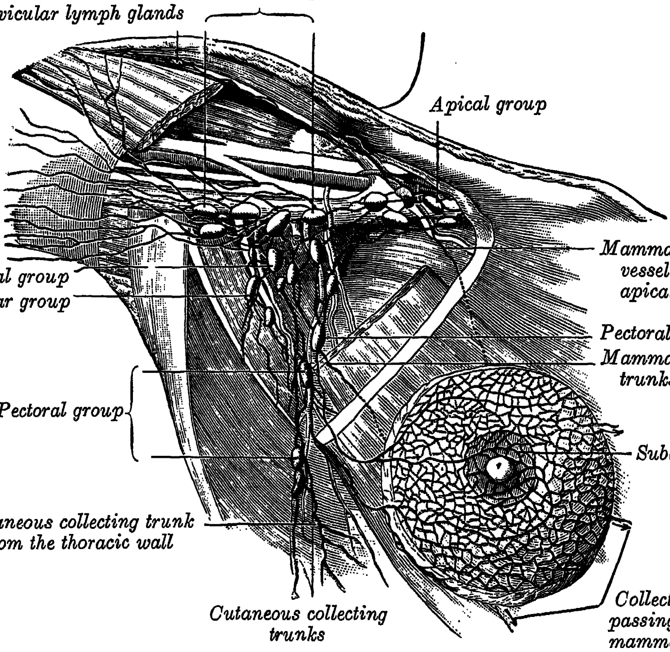
In the forearm and arm, the superficial lymph vessels run, for the most part, in company with the superficial veins. Collecting vessels from the hand pass into the forearm on all aspects of the wrist.

The vessels on the dorsum, after running vertically upwards parallel with one another, finally pass successively round the borders of the limb to join vessels on the front (fig. 805). The vessels on the front of the wrist pass up the forearm parallel with the median antebrachial vein to the cubital region.

Beyond this point they follow the medial border of the biceps muscle and, piercing the deep fascia at the anterior axillary fold, they end in the lateral group of axillary lymph glands.

The vessels on the lateral side of the wrist become associated in the forearm with the cephalic vein. They follow it to the level of the insertion of the Deltoid, where most of them incline medially to enter the lateral group of axillary lymph glands; a few continue with the cephalic vein and end in the infraclavicular glands. These lateral lymph vessels receive the vessels which wind round the lateral border of the limb from the posterior surface.

FIG. 804.—The lymph vessels of the mammary gland, and the axillary lymph glands. Semi-diagrammatic. (Poirier and Charpy.)



The vessels on the medial side of the wrist follow the basilic vein in the forearm. Just above the elbow some of them end in the supratrochlear lymph glands. The efferents from these, together with the medial vessels which have not ended in the supratrochlear glands, pierce the deep fascia with the basilic vein, and end in the lateral group of axillary glands or join the deep vessels. The vessels which wind round the medial border of the limb from the back join those of this medial set.

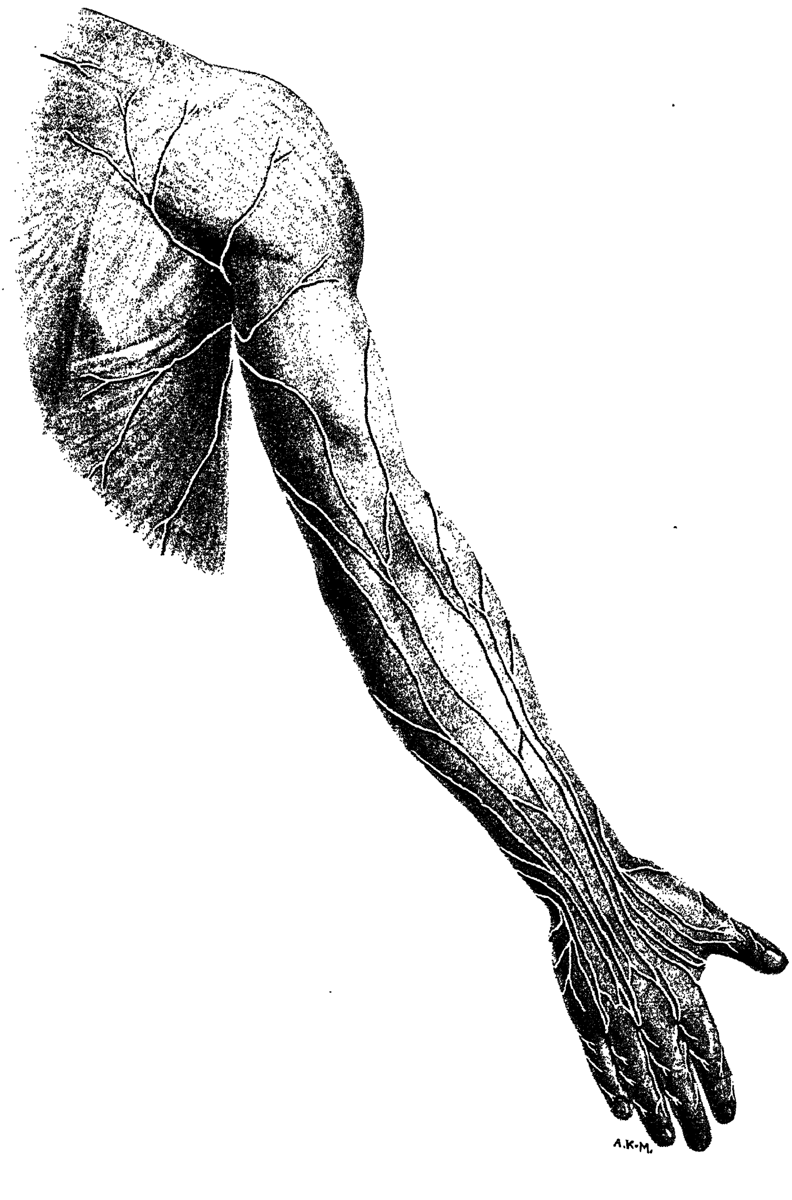
The collecting vessels from the front and back of the deltoid region pass respectively round the anterior and posterior axillary folds to end in the axillary lymph glands. The skin over the scapular region is drained by vessels which either end in the subscapular group of axillary glands, or follow the transverse cervical vessels and end in the lower deep cervical lymph glands.

The **lymphatic drainage of the deep tissues of the upper limb.**—The deep lymph vessels follow the main bundles of vessels and nerves (radial, ulnar, interosseous and brachial) and end in the lateral axillary lymph glands. They are less numerous than the superficial vessels, with which they communicate at intervals. Along their course there are a few deep lymph glands.

The muscles of the scapular region are drained by vessels which pass mainly to the subscapular group of axillary lymph glands. The lymph from the pectoral muscles is drained into the pectoral, central and apical groups.

The **lymphatic drainage of the breast.**—The *lymph vessels of the mammary gland* originate in a plexus in the interlobular spaces and in the walls of the lactiferous ducts. Those from the central part of the gland enter an intricate plexus which is situated beneath the areola. This plexus also receives the lymph vessels from the skin over the central part of the gland, and from the areola and nipple.

FIG. 805.—The lymphatic drainage of the superficial tissues of the upper limb. Posterior aspect. Semi-diagrammatic.



The efferent lymph vessels from the greater part of the mammary gland anastomose with the lymphatic plexus in the fascia on the Pectoralis major muscle, and subsequently end in the pectoral group of axillary glands; one vessel from the upper part of the gland pierces the Pectoralis major, and ends in the apical group of axillary glands. Through this fascial plexus also the lymph vessels from the medial part of the gland communicate with

(*a*) the internal mammary lymph glands (p. 876), and (*b*) with the lymph vessels of the opposite breast. The lymph vessels from the lower and medial parts of the mammary gland anastomose with a lymphatic plexus on the sheath of the upper part of the rectus abdominis, and on the front of the linea alba between the xiphoid process of the sternum and the seventh costal cartilage; although no direct communications between this plexus and the lymph vessels in the subperitoneal areolar tissue have been demonstrated by injection, the clinical and pathological investigations of W. Sampson Handley* leave no doubt that such exist.

Applied Anatomy.—Enlargement of the axillary lymph glands is very often found in malignant disease and also in infective processes implicating the upper part of the back and shoulder, the front of the chest and mammary gland, the upper part of the front and side of the abdomen, or the hand, forearm, and arm.

In operations for cancer of the breast the fascia covering the Pectoralis major and the adjoining muscles is removed over a wide area on account of the connexions and ramifications of the lymphatic plexus which it contains. In addition the axillary lymph glands, the sternocostal head of Pectoralis major and, frequently, the Pectoralis minor are taken away, in the endeavour to ensure, as far as possible, the complete removal of infected lymph vessels.

THE LYMPHATIC DRAINAGE OF THE LOWER LIMB

All the lymph from the lower limb, with the exception of that from the gluteal and ischial regions, traverses a terminal group of lymph glands in the groin. Before reaching these terminal glands the lymph may have passed through outlying, intermediary glands, which, however, are less numerous in the lower limb than they are in other parts of the body.

The terminal lymph glands are named the inguinal lymph glands, and they are in two sets: superficial and deep.

The **superficial inguinal lymph glands** (fig. 806) are themselves arranged in two groups, upper and lower. The *upper group*, usually 5 or 6 in number, forms a chain immediately below the inguinal ligament. The lateral members of the group receive afferent vessels from the gluteal region and from the adjoining part of the anterior abdominal wall below the umbilicus. The medial members of the group receive the superficial lymph vessels from the external genitalia (including in the female the vagina below the hymen), from the lower part of the anal canal and the circumanal region, from the adjoining part of the anterior abdominal wall below the umbilicus and uterine lymph vessels which run along the round ligament of the uterus.

The *lower group*, usually four or five in number, is disposed vertically along the terminal part of the long saphenous vein. They receive all the superficial lymph vessels of the lower limb, with the exception of those from the back and lateral side of the calf of the leg.

All the superficial inguinal lymph glands send their *efferents* to the external iliac lymph glands, some traversing the femoral canal, others passing in front of or lateral to the femoral vessels. In addition numerous vessels connect the individual glands one with another.

The **deep inguinal lymph glands** vary from one to three in number, and are placed deep to the fascia lata, on the medial side of the femoral vein. When three are present, the lowest is situated just below the junction of the long saphenous and femoral veins, the middle in the femoral canal, and the highest in the lateral part of the femoral ring. The middle one is the most inconstant, but the highest is frequently absent. They receive as afferents the deep lymph vessels which accompany the femoral vessels, the lymph vessels from the glans penis (or glans clitoridis), and, possibly, a few of the efferents from the superficial inguinal lymph glands; their efferents pass through the femoral canal to the external iliac lymph glands.

* *Cancer of the Breast and its Treatment*, 2nd edition, 1922, and "The Breast," *Choyce's System of Surgery*, 2nd edition, vol. ii.

FIG. 806.—The lymphatic drainage of the superficial tissues of the lower limb. Antero-medial aspect. Semi-diagrammatic.

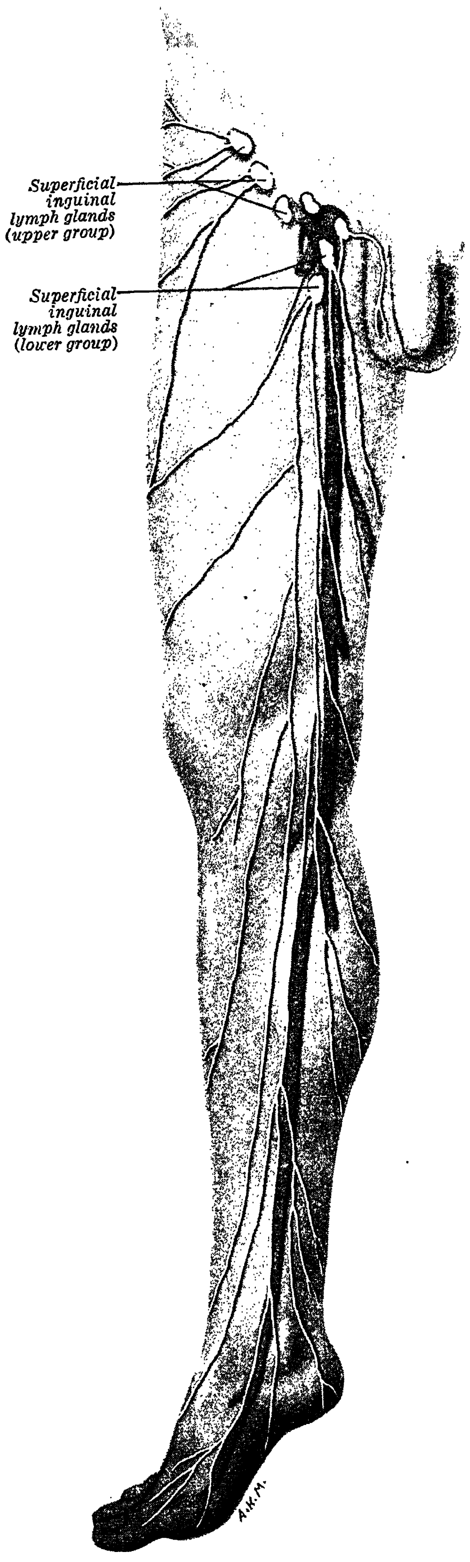
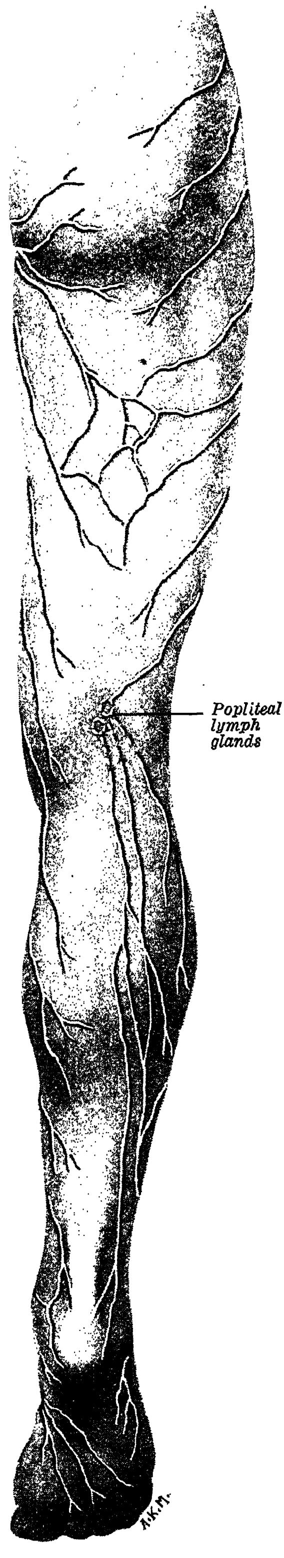


FIG. 807.—The lymphatic drainage of the superficial tissues of the lower limb. Posterior aspect. Semi-diagrammatic.



The outlying, intermediary lymph glands are few in number and are all deeply placed. Except for a gland which is sometimes present on the upper part of the interosseous membrane of the leg in relation with the anterior tibial vessels, they are restricted to a single group found in the popliteal fossa.

The **popliteal lymph glands** (fig. 807), small in size and six or seven in number, are imbedded in the fat contained in the popliteal fossa. One lies near the termination of the short saphenous vein, and drains the region from which this vein derives its tributaries. Another is placed between the popliteal artery and the posterior surface of the knee-joint; it receives the lymph vessels from the knee-joint together with those which accompany the genicular arteries. The remainder lie at the sides of the popliteal vessels, and receive as afferents the trunks which accompany the anterior and posterior tibial vessels. The efferents of the popliteal lymph glands pass almost entirely alongside of the femoral vessels to the deep inguinal lymph glands, but a few may accompany the long saphenous vein and end in the superficial inguinal lymph glands.

Applied Anatomy.—Inflammation and suppuration of the popliteal lymph glands are most commonly due to a sore on the lateral side of the heel.

The superficial inguinal lymph glands frequently become enlarged in diseases implicating the parts from which their lymph vessels originate. Thus in malignant or syphilitic affections of the prepuce and penis, or labia majora, in cancer of the scrotum, in abscess in the perineum, anus and lower part of the vagina, or in similar diseases affecting the skin and superficial structures in those parts, or the infra-umbilical part of the abdominal wall, or the gluteal region, the upper group of lymph glands is almost invariably enlarged, the lower group being implicated in diseases affecting the lower limb.

The lymphatic drainage of the superficial tissues of the lower limb.—The superficial lymph vessels begin in the lymphatic plexuses beneath the skin. Collecting vessels leave the foot in two sets—a medial set, whose vessels follow the general course of the long saphenous vein, and a lateral set, associated with the short saphenous vein.

The vessels of the *medial group* are larger and more numerous than those of the lateral group and begin on the tibial side of the dorsum of the foot. They ascend, some in front of the medial malleolus and others behind it, and accompany the long saphenous vein to the groin, where they end in the lower group of the superficial inguinal lymph glands. The vessels of the *lateral group* begin on the fibular side of the dorsum of the foot. Some of them cross the front of the leg to join the vessels of the medial group and so reach the lower group of the superficial inguinal lymph glands; others accompany the short saphenous vein and end in the popliteal lymph glands.

The superficial lymph vessels of the buttock pass round to the front of the limb and terminate in the upper group of the superficial inguinal lymph glands.

The lymphatic drainage of the deeper tissues of the lower limb.—The deep lymph vessels accompany the main blood-vessels of the limb and so comprise anterior tibial, posterior tibial, peroneal, popliteal and femoral sets. The deep lymph vessels of the foot and leg are interrupted by the popliteal lymph glands, but those from the thigh pass direct to the deep inguinal lymph glands.

The deep lymph vessels of the gluteal and ischial regions follow the course of the corresponding blood-vessels. Those accompanying the superior gluteal vessels end in a lymph gland which lies on the intrapelvic portion of the superior gluteal artery, near the upper border of the greater sciatic foramen. Those following the inferior gluteal vessels traverse one or two small lymph glands which lie below the piriformis muscle, and end in the internal iliac lymph glands.

THE LYMPHATIC DRAINAGE OF THE ABDOMEN AND PELVIS

The lymph from most of the abdominal wall and from all the abdominal viscera except a small part of the liver is returned to the blood-stream *viâ* the thoracic duct. The lymph vessels run with the corresponding arteries. The lymph glands comprise a large number of outlying, intermediary groups which

are placed along the arteries concerned, and a smaller number of terminal groups which are all in close relation with the abdominal aorta.

The **aortic lymph glands** comprise three principal groups of terminal lymph glands and one subsidiary group, each of which, though not sharply separated from the others topographically, nevertheless has its own particular area of drainage for the most part. These four groups are named according to their relation to the abdominal aorta, viz., pre-aortic, lateral aortic (right and left), and retro-aortic. The pre-aortic group drains the viscera supplied by the ventral branches of the aorta, i.e. the abdominal part of the alimentary canal and its derivatives. The lateral aortic groups drain the viscera and other structures supplied by the lateral and dorsal branches of the aorta and receive the efferents from the large, outlying groups associated with the iliac arteries. They therefore constitute the terminal groups for the suprarenal glands, kidneys, ureters, testes, ovaries, pelvic viscera (apart from the gut) and the posterior abdominal wall. The retro-aortic group has no particular area of drainage. Although it may have been primarily associated with the drainage of the posterior abdominal wall, it may be regarded as being formed by outlying members of both lateral aortic groups.

A. The Pre-aortic Lymph Glands and their Area of Drainage.

The **pre-aortic lymph glands** lie in close relationship with the anterior surface of the abdominal aorta. They receive lymph from the outlying, intermediary lymph glands associated with the subdiaphragmatic part of the alimentary canal, the pancreas, liver and spleen. Their efferents unite to form the *intestinal trunk*, which enters the cisterna chyli. They are divisible into cœliac, superior mesenteric and inferior mesenteric groups, which are in intimate relationship with the origins of the arteries of the same names.

In the alimentary canal the lymph vessels begin as minute subepithelial radicles, blind at one end but opening at the other into a fine *periglandular plexus*. In the small intestine a central lacteal occupies each villus. From the periglandular plexus vessels pierce the muscularis mucosæ and join the *submucous plexus*, efferents from which pass through the muscular coat, where they anastomose more or less freely, before entering the *subserous plexus*. The main collecting vessels arise from the subserous plexus and follow the course of the corresponding artery. Nodules of lymphoid tissue, either solitary or aggregated, are interposed along the course of the deeper vessels and function like lymph glands.

The collecting vessels from the alimentary canal pass through outlying groups of lymph glands before reaching the pre-aortic group.

1. **The cœliac lymph glands and their areas of drainage.**—The **cœliac lymph glands** lie on the front of the abdominal aorta close to the origin of the cœliac artery. They are the terminal group for the stomach, duodenum, liver, gall bladder, pancreas and spleen, and their afferents are derived from the outlying lymph glands which are placed along the branches of the cœliac artery. Of these there are, therefore, three main sets, viz.—gastric, hepatic and pancreaticosplenic.

(i) The **gastric lymph glands** (figs. 808, 809) consist of three sets, left gastric, right gastro-epiploic and pyloric.

The **left gastric lymph glands** (superior gastric lymph glands) accompany the left gastric artery and are divisible into three groups, viz. : (*a*) *upper*, on the stem of the artery ; (*b*) *lower*, accompanying the descending branches of the artery along the cardiac half of the lesser curvature of the stomach, between the two layers of the lesser omentum ; and (*c*) *paracardial*, disposed in a manner comparable to a chain of beads around the cardiac orifice of the stomach (Jamieson and Dobson).* They receive their afferents from the stomach, and also some vessels from the pylorus ; their efferents pass to the cœliac group of pre-aortic lymph glands.

The **right gastro-epiploic lymph glands** (inferior gastric lymph glands), four to seven in number, lie between the two layers of the greater omentum along the

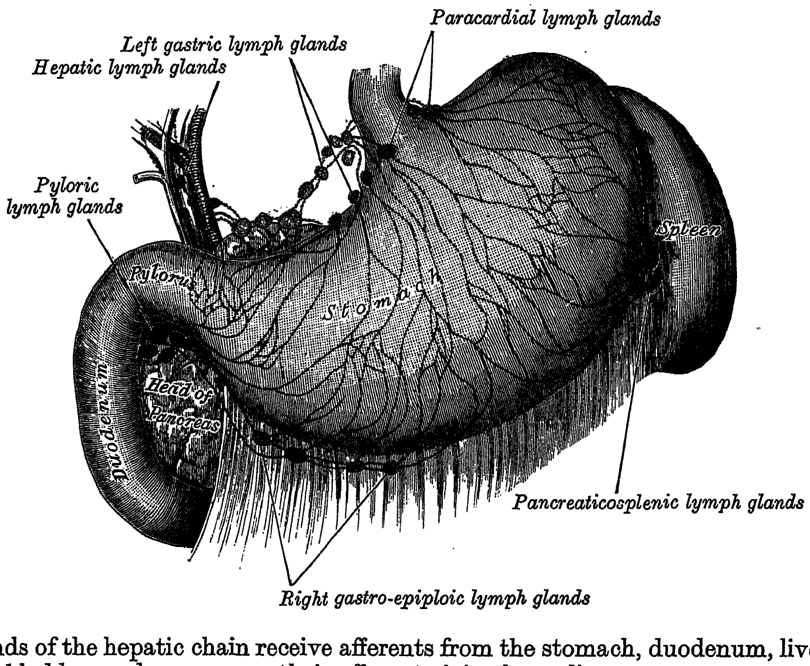
* J. K. Jamieson and J. F. Dobson, *Lancet*, April 20th and 27th, 1907.

pyloric half of the greater curvature of the stomach in relation with the vessels of the same name. They receive afferents from the stomach ; their efferents mostly pass to the pyloric lymph glands.

The **pyloric lymph glands** (subpyloric lymph glands of Jamieson and Dobson), four or five in number, lie in close relation to the bifurcation of the gastroduodenal artery, in the angle between the first and second parts of the duodenum ; an outlying member of this group is sometimes found above the duodenum on the right gastric artery. They receive afferents from the pyloric part of the stomach, the first part of the duodenum, and the right gastro-epiploic glands ; their efferents end in the cœliac group.

(ii) The **hepatic lymph glands** (fig. 808) are related to the stem of the hepatic artery, and extend upwards along the bile-duct, between the two layers of the lesser omentum, as far as the porta hepatis ; one member of this group, termed the *cystic lymph gland*, is placed near the neck of the gall-bladder. The lymph

FIG. 808.—The lymphatic drainage of the stomach, etc. (Jamieson and Dobson.)



glands of the hepatic chain receive afferents from the stomach, duodenum, liver, gall-bladder, and pancreas ; their efferents join the cœliac group.

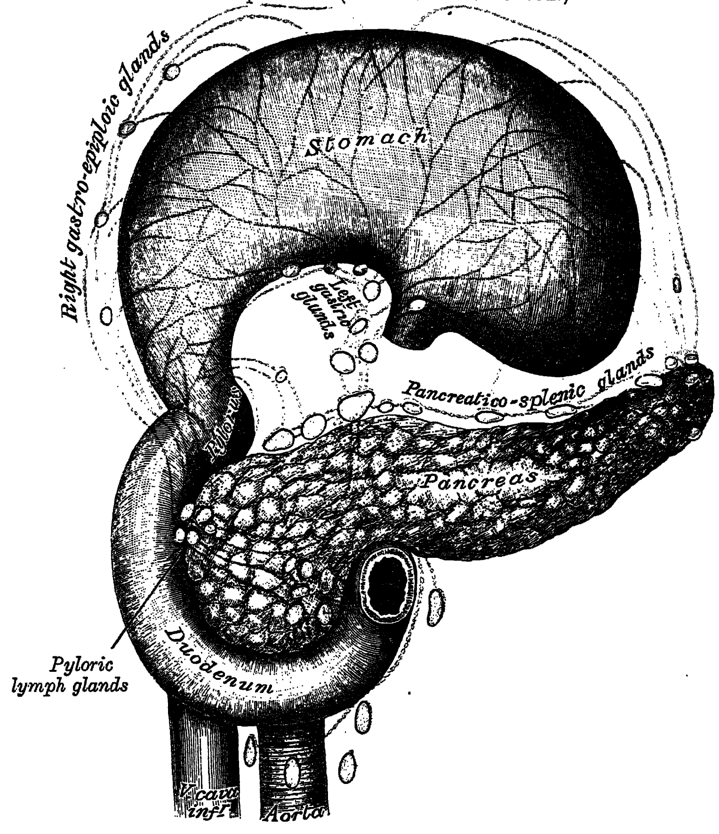
(iii) The **pancreaticosplenic lymph glands** (fig. 809) accompany the splenic (lienal) artery, and are situated in relation to the posterior surface and upper border of the pancreas ; one or two members of this group are found in the gastrosplenic ligament (Jamieson and Dobson, *loc. cit.*). Their afferents are derived from the stomach, spleen, and pancreas ; their efferents join the cœliac group.

(*a*) The *lymphatic drainage of the stomach and duodenum.*—The *lymph vessels of the stomach* (figs. 808, 809) are continuous at the cardiac orifice with those of the œsophagus, and at the pylorus with those of the duodenum. They follow the blood-vessels for the most part, and may be arranged in four sets. The first set accompanies the branches of the left gastric artery, receives tributaries from a large area on both surfaces of the stomach, and terminates in the left gastric lymph glands. Those of the second set drain the fundus and body of the stomach on the left of a line drawn vertically from the œsophagus ; they accompany, more or less closely, the short gastric and left gastro-epiploic vessels and end in the pancreaticosplenic lymph glands. The third set drains the right part of the greater curvature as far as the pyloric portion, and ends in the right gastro-epiploic lymph glands, the efferents of which pass to the pyloric group. Those of the fourth set drain the pyloric portion and pass to the hepatic, pyloric, and left gastric lymph glands. Although the vessels of

these sets communicate with one another, their valves are arranged so that the lymph flow is directed from the left part of the stomach towards the lesser curvature and from the right part towards the greater curvature.*

The *lymph vessels of the duodenum* comprise an anterior and a posterior set, which open into a series of small *pancreaticoduodenal lymph glands,* on the anterior and posterior parts of the groove between the head of the pancreas and the duodenum. The efferents of these glands run in two directions, upwards to the hepatic lymph glands, and downwards to the pre-aortic lymph glands around the origin of the superior mesenteric artery.

FIG. 809.—The lymph vessels and glands of the stomach, etc. The stomach has been turned upwards. (Jamieson and Dobson.)



(*b*) The *lymphatic drainage of the liver and gall-bladder.*—The collecting vessels from the liver are divisible into two main groups—superficial and deep.

The *superficial lymph vessels of the liver* run in the subserous areolar tissue over the whole surface of the organ. They drain in four directions. (1) From the middle part of the posterior surface, from the caudate lobe, from the posterior part of the convex surfaces of both lobes near the attachment of the falciform ligament, and from the posterior part of the inferior surface of the right lobe the vessels accompany the inferior vena cava and end in glands round the terminal part of that vessel. (2) The vessels from the remainder of the inferior surface, and from the anterior part of the convex surface of both lobes near the attachment of the falciform ligament converge on the porta hepatis and end in the hepatic group of glands. (3) From the posterior part of the left lobe a few vessels pass towards the œsophageal opening in the diaphragm and end in the paracardial glands. (4) From the remainder of the convex surface of the right lobe one or two trunks accompany the phrenic artery across the right crus of the Diaphragm and end in the cœliac glands.

* J. H. Gray, *Journal of Anatomy,* vol. lxxi. 1937.

The *deep lymph vessels* of the liver join one another to form ascending and descending trunks. The ascending trunks accompany the hepatic veins and, passing through the vena caval opening, end in the glands round the termination of the inferior vena cava. The descending trunks emerge from the porta hepatis and end in the hepatic lymph glands.

The collecting vessels from the gall-bladder pass to the cystic gland and the hepatic glands ; those from the bile-ducts end in the hepatic glands alongside the bile-duct and in the upper pancreaticosplenic glands.

(*c*) The *lymphatic drainage of the pancreas*.—The lymph vessels of the pancreas follow the course of its blood-vessels. Most of them end in the pancreaticosplenic glands, but some end in the glands along the pancreaticoduodenal vessels and others in the superior mesenteric group of the pre-aortic glands.

(*d*) The *lymphatic drainage of the spleen*.—The collecting vessels from the spleen comprise a superficial set and a deep set, both of which end in the pancreaticosplenic lymph glands.

2. The **superior and inferior mesenteric lymph glands and their area of drainage**.—The superior and inferior mesenteric lymph glands lie on the front of the abdominal aorta close to the points of origin of the arteries of the same names. They are the terminal groups for the alimentary canal from the duodenojejunal flexure to the upper part of the rectum, and receive afferents from the outlying groups which lie along the jejunal, ileal, colic and superior rectal arteries.

(*a*) The *lymphatic drainage of the jejunum and ileum*.—The lacteals pass between the layers of the mesentery, but, before reaching the superior mesenteric glands, the lymph passes through the **lymph glands of the mesentery**. These vary from one hundred to one hundred and fifty in number and comprise three sets, viz.—one lying close to the wall of the intestine amongst the terminal twigs of the jejunal and ileal arteries : a second, in relation to the loops and primary branches of the same vessels ; and a third, along the upper part of the trunk of the superior mesenteric artery. The lymph from the terminal few inches of the ileum follows the ileal branch of the ileocolic artery to end in the ileocolic lymph glands.

Applied Anatomy.—Enlargement of the mesenteric lymph glands is seen in most diseased conditions of the intestinal tract, and is well marked in enteric fever, tuberculous ulceration or malignant growths of the bowel. The enlarged lymph glands can often be palpated through the wall of the abdomen.

(*b*) The *lymphatic drainage of the colon*.—The lymph from the colon drains into both the superior and the inferior mesenteric lymph glands, in accordance with the arterial supply of this part of the gut. Outlying groups of lymph glands, which are placed along the course of the colic, ileocolic and superior rectal arteries, are interposed on the pathway of the colic lymph vessels.

The **lymph glands of the colon** are divided into four groups (Jamieson and Dobson, *loc. cit.*) : (*a*) epicolic, (*b*) paracolic, (*c*) intermediate colic and (*d*) terminal colic.

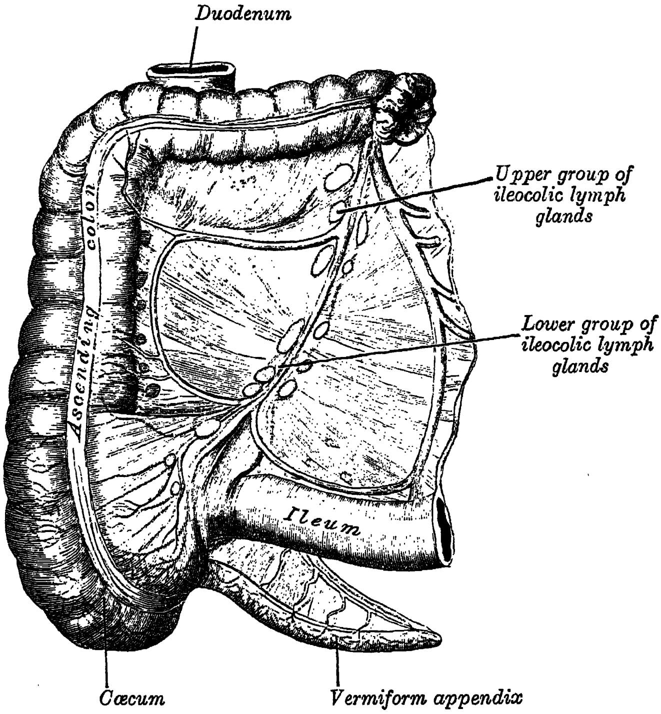
The *epicolic lymph glands* are merely minute nodules situated on the wall of the gut. The *paracolic lymph glands* lie along the medial borders of the ascending and descending colon, and along the mesenteric borders of the transverse and pelvic colon. The *intermediate colic lymph glands* lie along the right, middle and left colic arteries. The *terminal colic lymph glands* are placed on the main trunks of the superior and inferior mesenteric arteries, and are in direct continuity with the corresponding pre-aortic lymph glands.

The **pararectal lymph glands** lie in contact with the muscular coat of the rectum. Their efferents pass to an intermediate group around the superior rectal artery (superior hæmorrhoidal artery), and thence to the lymph glands at the origin of the inferior mesenteric artery. Others pass to the lymph glands at the bifurcation of the common iliac artery.

The **ileocolic lymph glands** (figs. 810, 811), from ten to twenty in number, form a chain around the ileocolic artery, but show a tendency to subdivision into two groups, one near the duodenum and another on the lower part of the trunk of the artery. Where the vessel divides into its terminal branches the

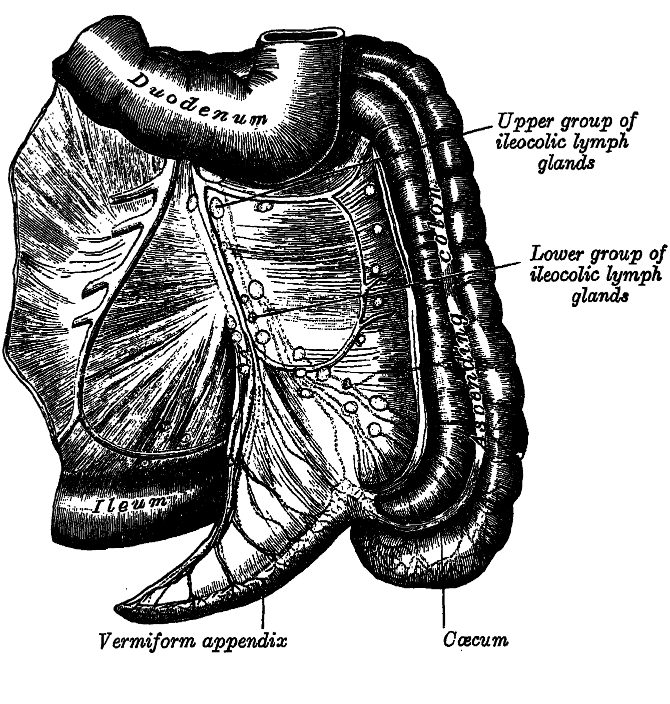
chain is broken up into several groups, viz.: (*a*) *ileal*, in relation to the ileal branch of the artery; (*b*) *anterior ileocolic*, usually three in number, in the

FIG. 810.—The lymph vessels and glands of the cæcum and vermiform appendix. Anterior aspect. (Jamieson and Dobson.)



ileocæcal fold, near the wall of the cæcum; (*c*) *posterior ileocolic*, mostly placed in the angle between the ileum and the colon, but partly lying behind the

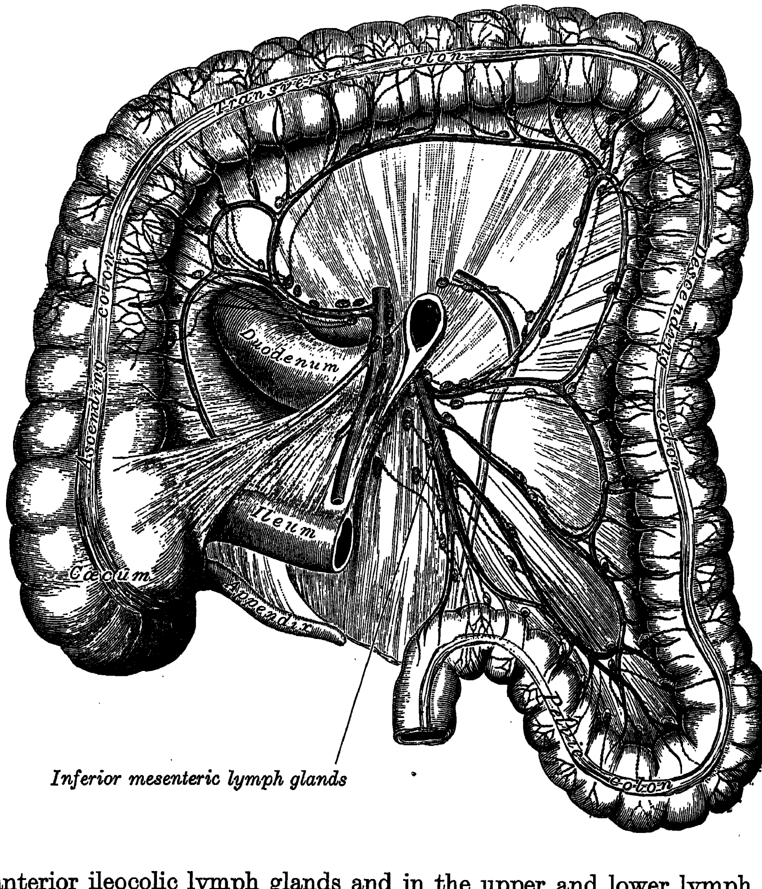
FIG. 811.—The lymph vessels and glands of the cæcum and vermiform appendix. Posterior aspect. (Jamieson and Dobson.)



cæcum at its junction with the ascending colon ; (*d*) a single gland in the mesentery of the vermiform appendix.

The *lymph vessels of the vermiform appendix and cæcum* (figs. 810, 811) are numerous, since there is a large amount of lymphoid tissue in the walls of these parts of the digestive tube. From the body and tip of the vermiform appendix eight to fifteen vessels ascend between the layers of its mesentery, one or two being interrupted in the lymph gland which lies in this peritoneal fold. They unite to form three or four vessels, which end partly in the lower and partly in the upper lymph glands of the ileocolic chain. The vessels from the root of the vermiform appendix and from the cæcum comprise an anterior and a posterior group. The anterior vessels pass in front of the cæcum, and end in

FIG. 812.—The lymph vessels and glands of the colon. (Jamieson and Dobson.)



the anterior ileocolic lymph glands and in the upper and lower lymph glands of the ileocolic chain ; the posterior vessels ascend over the back of the cæcum and terminate in the posterior ileocolic lymph glands and in the lower lymph glands of the ileocolic chain.

Lymph vessels of the colon (fig. 812).—The lymph vessels of the ascending and transverse parts of the colon end in the superior mesenteric lymph glands, after traversing the right colic and middle colic lymph glands. Those of the descending and pelvic parts of the colon are interrupted by the small lymph glands on the branches of the left colic arteries, and ultimately end in the preaortic lymph glands around the origin of the inferior mesenteric artery.

(*c*) The *lymphatic drainage of the rectum and anal canal*.—The lymph vessels of the *anal canal* accompany the inferior rectal (inferior hæmorrhoidal) vessels across the ischiorectal fossa, run with the internal pudendal vessels through the pudendal canal, and open into the internal iliac lymph glands. The lymph vessels from the *lower part of the rectum* join in a plexus on the levator ani, and then enter the internal iliac lymph glands ; those from the *upper part of the*

rectum accompany the superior rectal vessels, and, after traversing the pararectal lymph glands, enter the lymph glands near the bifurcation of the common iliac artery; vessels pass from the highest pararectal lymph glands to the lymph glands in the pelvic mesocolon, and the efferents of these glands end in the pre-aortic lymph glands around the origin of the inferior mesenteric artery.

The *lymph vessels of the anus* pass forwards and end with those of the skin of the perineum and scrotum in the superficial inguinal lymph glands.

B. The Lateral Aortic Lymph Glands and their Area of Drainage.

The lateral aortic lymph glands lie on each side of the abdominal aorta in front of the medial margin of the Psoas major, the crus of the Diaphragm and the sympathetic trunk. On the right side some members of the group lie to the lateral side of the inferior vena cava and in front of the vessel near the termination of the right renal vein. Afferents reach the lateral aortic glands from the structures supplied by the lateral and dorsal branches of the aorta and from the outlying lymph glands associated with the iliac arteries and their branches. Efferents from the lateral aortic lymph glands on each side form the *lumbar trunk*, and the right and left lumbar trunks terminate in the cisterna chyli. A few efferents may pass to the pre-aortic and retro-aortic groups.

The lymph vessels from the kidney and the abdominal portion of the ureter, from the posterior abdominal wall, from the testis in the male, and from the ovary, the uterine tube and the upper part of the uterus in the female all pass directly to the lateral aortic lymph glands without being interrupted by any intermediary group. The lymph vessels from the pelvis and most of the pelvic viscera and from the lateral and anterior parts of the abdominal wall pass first through outlying groups which are associated for the most part with the iliac arteries and some of their branches. They include the following groups:

Common iliac.	Inferior epigastric.
External iliac.	Circumflex iliac.
Internal iliac.	Sacral.

The *common iliac lymph glands*, four to six in number, are grouped behind and on the sides of the common iliac artery, one or two (subaortic) being placed below the bifurcation of the aorta in front of the fifth lumbar vertebra or the promontory of the sacrum. They receive afferents from the external and internal iliac lymph glands, and send their efferents to the lateral aortic group.

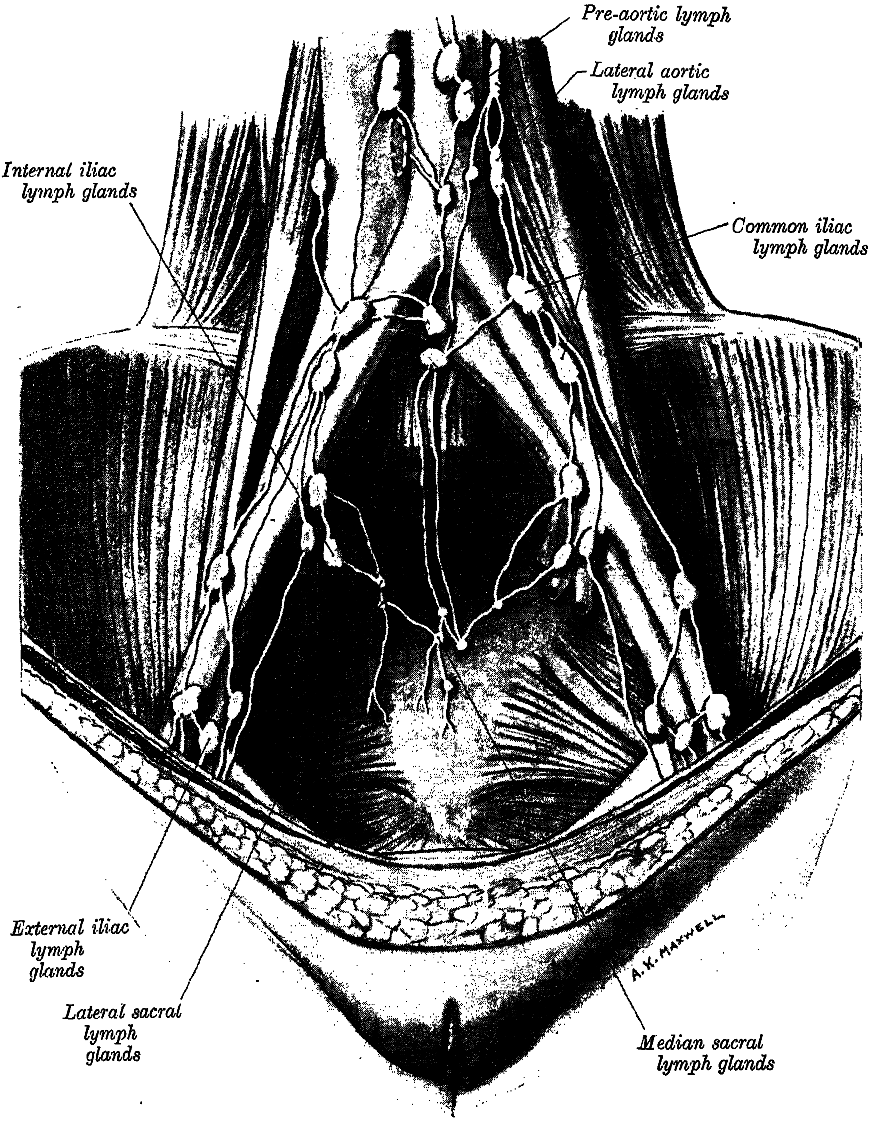
The *external iliac lymph glands*, about eight to ten in number, lie along the external iliac vessels. They are usually in three groups, one on the lateral side, another on the medial side, and a third in front of the vessels, but the last-named group is inconstant. They receive afferents from the inguinal lymph glands (p. 862), from the deeper layers of the infra-umbilical part of the abdominal wall, from the deep part of the adductor region of the thigh, from the glans penis vel clitoridis, the membranous urethra, the prostate, the fundus of the urinary bladder, the cervix uteri and part of the vagina. Their efferents pass to the common iliac lymph glands. The *inferior epigastric* and the *circumflex iliac lymph glands*, which are associated with the vessels of the same names and drain the corresponding areas, are outlying members of the external iliac group. They are inconstant in number.

The *internal iliac lymph glands* surround the internal iliac vessels. They receive afferents from all the pelvic viscera, from the deeper parts of the perineum, and from the muscles of the buttock and back of the thigh. Their efferents pass to the common iliac lymph glands. The *sacral lymph glands*, which are placed along the median and lateral sacral vessels, and the *obturator lymph gland*, which is sometimes present in the obturator canal, are outlying members of the internal iliac group.

1. **The lymphatic drainage of the urinary tract.**—(*a*) The *kidney*.—The

lymph vessels of the kidney begin in three plexuses : one in the substance of the organ between and around the renal tubules ; a second beneath the fibrous capsule ; and a third which communicates freely with the subcapsular plexus, in the renal fat. The collecting vessels from the intrarenal plexus form four or five trunks which follow the renal vein and end in the lateral aortic lymph glands ; as they issue from the hilum they are joined by the collecting

FIG. 813.—The lymph glands of the pelvis. Semi-diagrammatic.

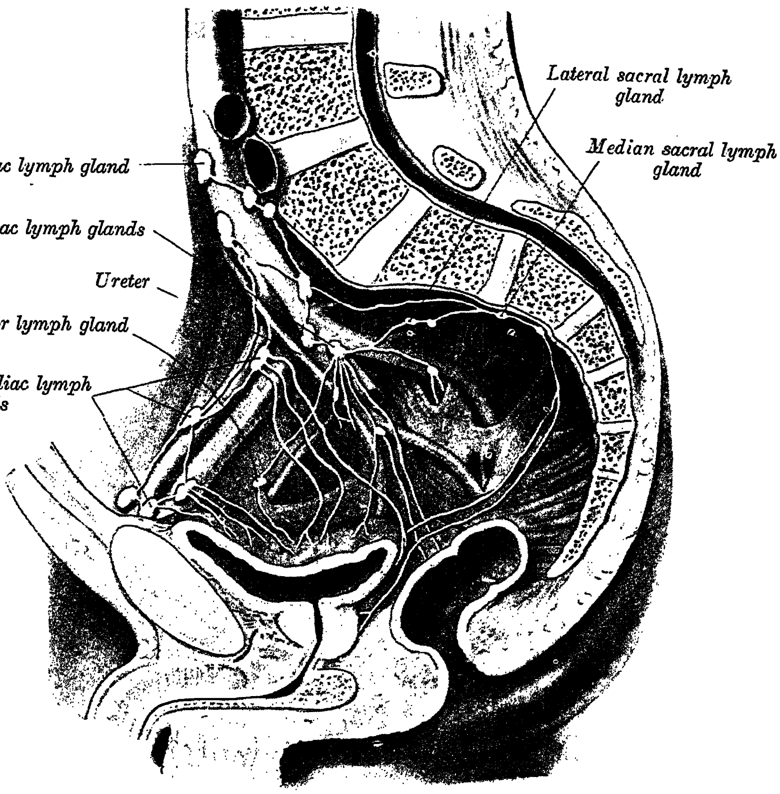


vessels from the subscapular plexus. The plexus in the renal fat drains directly into the lateral aortic lymph glands.

(*b*) The *ureter*.—The lymph vessels of the ureter begin in submucous, intramuscular and adventitial plexuses which communicate with each other. The collecting vessels from the upper part of the ureter may join the renal collecting vessels or may pass directly to the lateral aortic lymph glands near the origin of the testicular (or ovarian) artery ; those from the succeeding part pass to the common iliac lymph glands ; and those from the pelvic part of the ureter may end in the common, the external or the internal iliac lymph glands.

(c) The *bladder*.—The lymph vessels of the bladder take origin in three plexuses—a submucous,* an intramuscular and an extramuscular. The collecting vessels, nearly all of which end in the external iliac lymph glands, are arranged in three sets : the vessels from the region of the trigone emerge on the base of the bladder and run upwards and laterally ; those from the superior surface converge on the posterolateral angle and then pass upwards and laterally across the lateral umbilical ligament to reach the external iliac glands (one of the vessels of this set may go to the internal or common iliac group) ; those from the inferolateral surface pass towards its upper part and then run with those from the superior surface. Minute nodules of lymphoid tissue may be found along the course of the lymph vessels of the bladder.

FIG. 814.—The lymphatic drainage of the urinary bladder. Semi-diagrammatic.



(d) The *urethra*.—(i) The vessels from the prostatic and membranous parts in the male, and from the whole urethra in the female, pass mainly to the internal iliac lymph glands ; a few may end in the external iliac glands. The vessels from the membranous part accompany the internal pudendal artery.

(ii) The vessels of the spongy urethra in the male accompany those of the glans penis and end in the deep inguinal lymph glands (p. 862). Some may terminate in the superficial inguinal glands, and others may pass along the inguinal canal to reach the external iliac group.

2. **The lymphatic drainage of the male reproductive organs.**—(a) The *testis*.—The lymph vessels of the testis commence in two plexuses—a superficial, under the tunica vaginalis, and a deep, in the substance of the testis and in the epididymis. Four to eight collecting trunks ascend in the spermatic cord and accompany the testicular vessels as they lie on the psoas major muscle ; they end in the lateral aortic and pre-aortic lymph glands.†

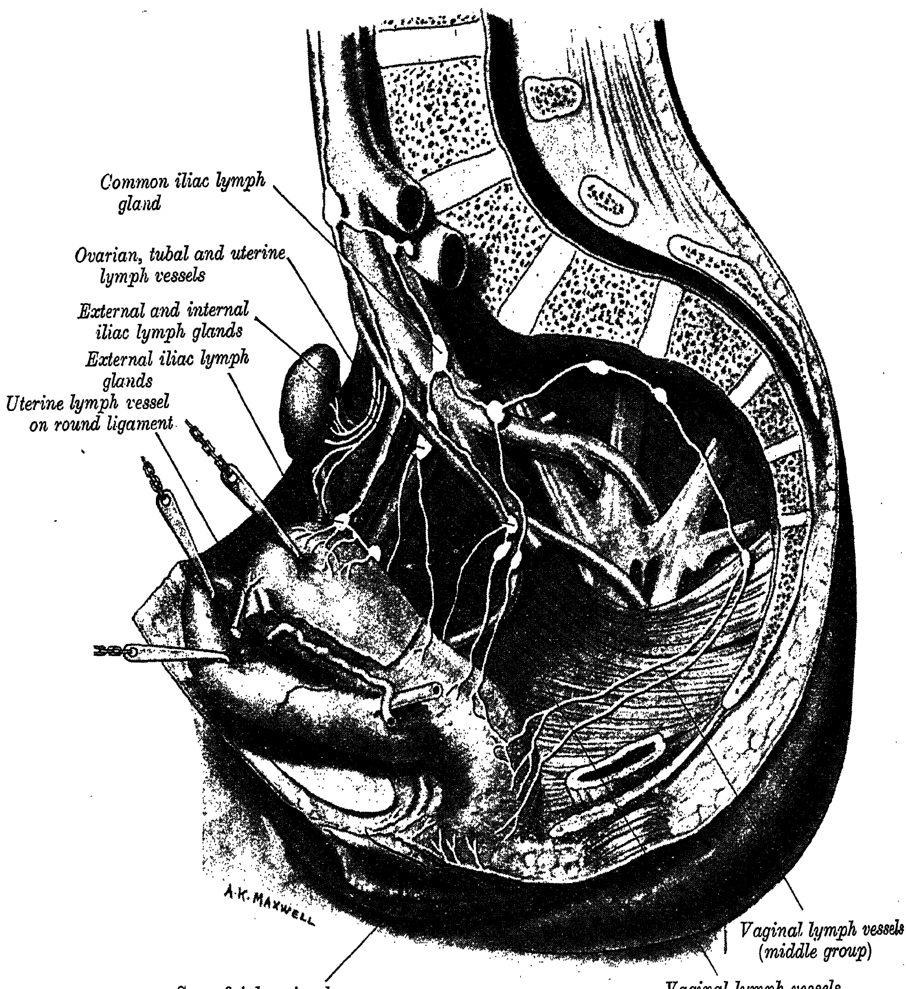
* See *Médecine opératoire des voies urinaires*, J. Albarran, Paris, 1909 ; and *Anatomie des lymphatiques de l'homme*, H. Rouvière, Paris, 1932.

† "The Lymphatics of the Testicle," by J. K. Jamieson and J. F. Dobson, *Lancet*, February 19th, 1900.

(*b*) The *vas deferens, seminal vesicle and prostate.*—The collecting vessels from the vas deferens end in the external iliac lymph glands. Those from the seminal vesicle go to both the internal and external iliac groups.

The prostatic lymph vessels terminate chiefly in the internal iliac and sacral lymph glands ; a trunk from the posterior surface passes with the lymph vessels of the bladder to the external iliac glands, and another from the anterior surface gains the internal iliac group by joining the lymph vessels of the membranous urethra.

FIG. 815.—The lymphatic drainage of the female reproductive organs. Semi-diagrammatic. (After Cunéo and Marcille.)



(*c*) The *scrotum and penis.*—The skin covering these parts is drained by vessels which, together with those of the whole of the perineal skin, pass along the course of the external pudendal blood-vessels to the superficial inguinal lymph glands. The lymph vessels of the glans penis pass to the deep inguinal and external iliac groups.

3. **The lymphatic drainage of the female reproductive organs.**—(*a*) The *ovary.*—The lymph vessels of the ovary, like those of the testis, ascend along the ovarian artery to the lateral aortic and pre-aortic lymph glands.

(*b*) The *uterus and uterine tube.*—The lymph vessels of the uterus comprise two sets : a superficial, beneath the peritoneum, and a deep, in the substance of the uterine wall. The collecting vessels from the cervix pass in three

directions: laterally in the parametrium to the external iliac lymph glands; posterolaterally to the internal iliac glands; and backwards in the sacrogenital fold to the sacral glands. Most of the vessels from the body and fundus of the uterus and from the uterine tube accompany those of the ovary to the lateral aortic and pre-aortic glands; a few, however, pass to the external iliac glands. The region near the point of entry of the uterine tube is drained by vessels which accompany the round ligament and so reach the superficial inguinal lymph glands. The lymph vessels of the uterus enlarge greatly during pregnancy.

(c) The *vagina.*—The lymph vessels of the vagina anastomose with those of the cervix uteri, the rectum and the vulva. They are in three groups, but the areas drained by the three sets are not sharply demarcated. The vessels from the upper part accompany the uterine artery to the external iliac lymph glands. The middle part is drained by vessels which accompany the vaginal artery and end in the external iliac glands. The vessels of the vagina below the hymen, the vulva, and the skin of the perineum as a whole pass to the superficial inguinal lymph glands.

4. The **lymphatic drainage of the abdominal wall.**—The lymph vessels of the abdominal wall are in two sets: superficial, in the superficial fascia; and deep, draining the muscles, etc.

The *superficial lymph vessels* accompany the superficial blood-vessels. Those from the loin and buttock run with the superficial circumflex iliac vessels, and those from the skin of the anterior wall below the umbilicus with the superficial epigastric vessels. Both sets pass to the superficial inguinal lymph glands. The part above the umbilicus is drained by vessels most of which run obliquely upwards to end in the pectoral and subscapular groups of the axillary lymph glands; a few end in the internal mammary lymph glands (p. 876).

The *deep lymph vessels* accompany the deep arteries. Those from the posterior abdominal wall pass directly, along the course of the lumbar arteries, to the lateral aortic and retro-aortic lymph glands; those from the upper part of the anterior abdominal wall run with the superior epigastric vessels to reach the internal mammary lymph glands; those of the lower part end in the circumflex iliac, inferior epigastric, and external iliac lymph glands. The lymph vessels of the pelvic wall follow the internal iliac artery and its parietal branches and end in the iliac or lateral aortic lymph glands.

THE LYMPHATIC DRAINAGE OF THE THORAX

The lymphatic drainage of the thorax may be considered under two headings: (*A*) drainage of the thoracic walls, and (*B*) drainage of the thoracic contents, and it should be noted that the glands on the lymphatic pathways of the thorax cannot be divided into terminal and outlying groups, as, with a few exceptions, the lymph glands concerned drain into the thoracic duct or the right lymphatic duct or one of their larger tributaries.

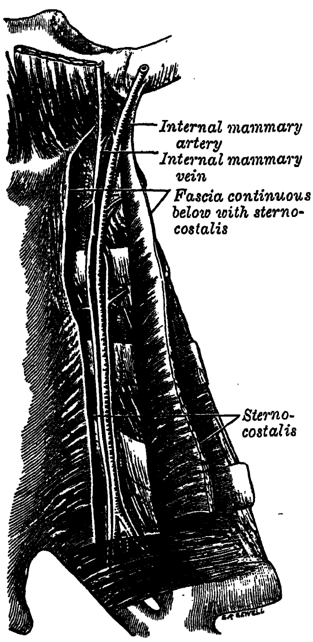
A. Lymphatic Drainage of the Thoracic Walls.

1. The *superficial tissues.*—The superficial lymph vessels of the thoracic wall ramify beneath the skin and converge on the axillary lymph glands. Those over the trapezius and latissimus dorsi run forwards and unite to form about ten or twelve trunks which end in the subscapular group. Those over the pectoral region, including the vessels from the skin covering the peripheral part of the mammary gland, run backwards, and those over the serratus anterior upwards, to the pectoral group. Others near the lateral margin of the sternum pass inwards between the rib cartilages and end in the internal mammary lymph glands, while the vessels of opposite sides anastomose across the front of the sternum. A few vessels from the upper part of the pectoral region ascend over the clavicle to the inferior deep cervical lymph glands.

2. The *deeper tissues*.—The lymph vessels from the deeper tissues of the thoracic walls drain mainly into three sets of glands—the internal mammary, the intercostal and the diaphragmatic.

(*a*) The **internal mammary lymph glands** (sternal lymph glands) are four or five in number on each side, and are placed (fig. 816) at the anterior ends of the intercostal spaces, by the side of the internal mammary artery.* They derive afferents from the medial part of the mammary gland, from the deeper structures of the anterior abdominal wall above the level of the umbilicus, from the upper surface of the liver through a small group of lymph glands which lies behind the xiphoid process, and from the deeper parts of the anterior portion of the thoracic wall. Their efferents usually unite to form a single trunk; this may open directly into the junction of the internal jugular and subclavian veins, or that of the right side may join the right subclavian trunk, and that of the left the thoracic duct.

FIG. 816.—The right sternal or internal mammary lymph glands (E. P. Stibbe).



(*b*) The **intercostal lymph glands** lie in the posterior parts of the intercostal spaces and in relation to the heads and necks of the ribs. They receive the deep lymph vessels from the postero-lateral aspect of the chest; some of these vessels are interrupted by small lateral intercostal lymph glands. The efferents of the lymph glands in the lower four or five spaces unite to form a trunk which descends and opens either into the cisterna chyli or into the commencement of the thoracic duct. The efferents of the lymph glands in the upper spaces of the left side end in the thoracic duct; those of the corresponding right spaces, in the right lymphatic duct.

(*c*) The **diaphragmatic lymph glands** lie on the thoracic surface of the diaphragm, and consist of three sets, anterior, right and left lateral.

The *anterior* set comprises (*a*) two or three small lymph glands behind the base of the xiphoid process, which receive afferents from the convex surface of the liver, and (*b*) one or two lymph glands on each side near the junction of the seventh rib with its cartilage, which receive lymph vessels from the front part of the Diaphragm. The efferent vessels of the anterior set pass to the internal mammary lymph glands.

The *lateral* sets consist of two or three lymph glands on each side close to where the phrenic nerves enter the Diaphragm. On the right side some of the lymph glands of this group lie within the fibrous wall of the pericardium on the front of the termination of the inferior vena cava. The afferents of this set are derived from the middle part of the Diaphragm, those on the right side also receiving afferents from the convex surface of the liver. Their efferents pass to the posterior mediastinal lymph glands.

The *posterior* set consists of a few lymph glands situated on the back of the crura of the Diaphragm, and connected on the one hand with the lumbar lymph glands, and on the other with the posterior mediastinal lymph glands.

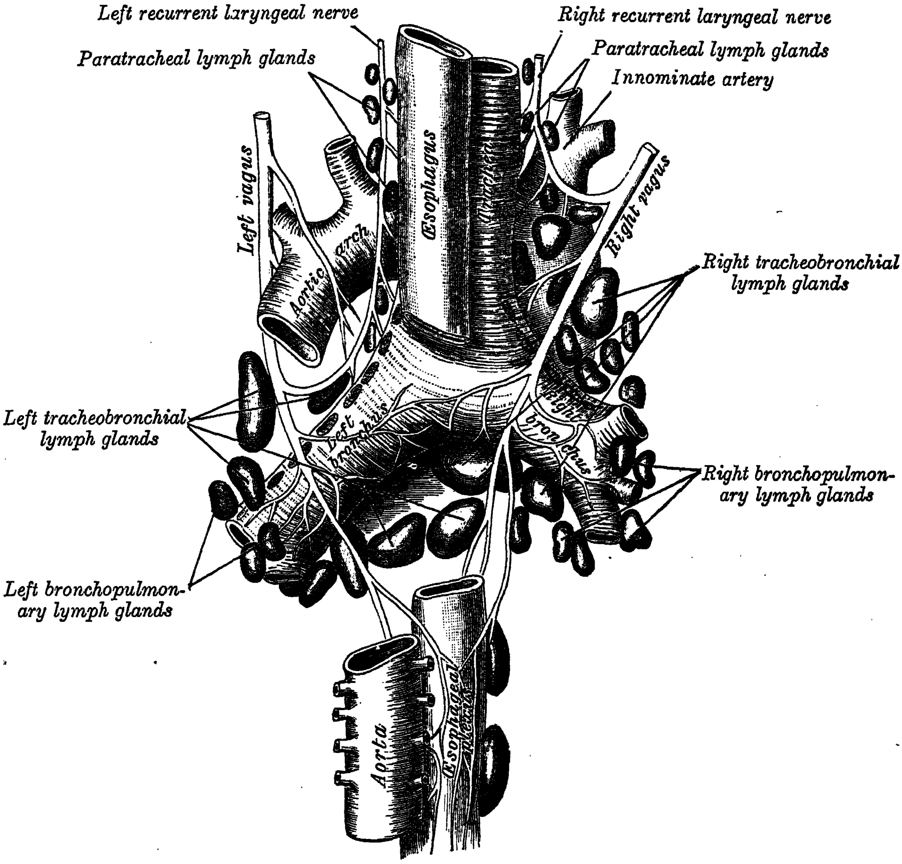
The collecting lymph vessels from the deeper tissues comprise:

(*a*) The lymph vessels of the muscles which lie on the ribs: most of these end in the axillary lymph glands, but some from the Pectoralis major pass to the internal mammary lymph glands. (*b*) The intercostal lymph vessels which drain the Intercostales and parietal pleura; those from the anterior half of the thoracic wall and pleura end in the internal mammary lymph glands; those from the posterior half, in the intercostal lymph glands. (*c*) The lymph vessels of the Diaphragm, which form two plexuses, one on its thoracic and another on its abdominal surface; these plexuses anastomose freely with each other, and

* E. P. Stibbe, *Journal of Anatomy*, vol. lii.

are best marked on the parts covered respectively by the pleuræ and peritoneum. *The plexus on the thoracic surface* unites with the lymph vessels of the costal and mediastinal parts of the pleura, and its efferents consist of three groups: anterior, passing to the anterior diaphragmatic lymph glands, which lie near the junction of the seventh rib with its cartilage; middle, to the lymph glands on the œsophagus and to those around the termination of the inferior vena cava; and posterior, to the lymph glands which surround the aorta at the point where this vessel leaves the thoracic cavity. *The plexus on the abdominal surface* is composed of fine vessels, and anastomoses with the lymph vessels

FIG. 817.—The tracheobronchial lymph glands. (From a figure designed by M. Hallé.)



of the liver and, at the periphery of the Diaphragm, with those of the subperitoneal tissue. The efferents from the right half of this plexus terminate partly in a group of lymph glands on the trunk of the corresponding phrenic artery, while others end in the right lateral aortic lymph glands. Those from the left half of the plexus pass to the pre-aortic and lateral aortic lymph glands and to the lymph glands on the terminal portion of the œsophagus.

B. Lymphatic Drainage of the Thoracic Contents.

The lymph from the thoracic viscera traverses one or other of three sets of lymph glands, viz. innominate, posterior mediastinal and tracheobronchial, before entering the thoracic duct, the right lymphatic duct or another lymph vessel which itself enters one of the great veins at the root of the neck.

The **innominate lymph glands** (anterior mediastinal lymph glands) are placed in the anterior part of the superior mediastinum, in front of the innominate veins and the large arterial trunks which arise from the aortic arch. They

receive afferents from the thymus and pericardium, and from the lateral diaphragmatic lymph glands; their efferents unite with those of the tracheobronchial lymph glands, to form the right and left bronchomediastinal trunks.

The **posterior mediastinal lymph glands** lie behind the pericardium in relation to the œsophagus and descending thoracic aorta. Their afferents are derived from the œsophagus, the posterior part of the pericardium, the Diaphragm, and, occasionally, the left lobe of the liver. Their efferents mostly end in the thoracic duct, but some join the tracheobronchial lymph glands.

The **tracheobronchial lymph glands** (fig. 817) form five main groups, and include some of the largest lymph glands in the body: (*a*) *paratracheal*, at the sides of the thoracic part of the trachea; (*b*) *superior tracheobronchial*, in the angles between the lower part of the trachea and bronchi; (*c*) *inferior tracheobronchial* in the angle between the two bronchi; (*d*) *bronchopulmonary*, in the hilum of each lung; and (*e*) *pulmonary*, in the lung substance, on the larger branches of the bronchi. These groups are not sharply demarcated from one another. The pulmonary lymph glands become continuous at the hilum of the lung with the bronchopulmonary glands, and they in turn are continuous with the inferior and superior tracheobronchial glands, while the latter are continuous with the paratracheal group. The afferents of the tracheobronchial lymph glands drain the lungs and bronchi, the thoracic part of the trachea, and the heart; some of the efferents of the posterior mediastinal lymph glands also end in this group. Their efferent vessels ascend upon the trachea and unite with efferents of the internal mammary and innominate lymph glands to form the *right* and *left bronchomediastinal trunks*. The right bronchomediastinal trunk may join the right lymphatic duct, and the left the thoracic duct, but more frequently they open independently of these ducts into the junction of the internal jugular and subclavian veins of their own side.

Applied Anatomy.—In all town-dwellers there are continually being swept into these lymph glands from the bronchi and alveoli large quantities of the dust and black carbonaceous pigment that are so freely inhaled in cities. In tuberculosis of the lungs these lymph glands are practically always infected; they enlarge, being filled with tuberculous deposits that may soften, or become fibrous, or calcify. Not infrequently an enlarged tuberculous lymph gland perforates into a bronchus, discharging its contents into the tube. When this happens there is great danger of acute pulmonary tuberculosis, the infecting gland-substance being rapidly spread throughout the bronchial system by the coughing induced by its presence in the air-passages.

1. The *lymphatic drainage of the heart.*—The lymph vessels of the heart consist of two plexuses: (*a*) deep, immediately under the endocardium, and (*b*) superficial, subjacent to the visceral pericardium. The deep plexus opens into the superficial, the efferents of which form left and right collecting trunks. The *left* trunks, two or three in number, ascend in the anterior interventricular groove, receiving, in their course, vessels from both ventricles. On reaching the atrioventricular (coronary) sulcus they are joined by a large trunk from the diaphragmatic surface of the heart, and then unite to form a single vessel, which ascends between the pulmonary artery and the left atrium, and ends, usually, in one of the inferior tracheobronchial lymph glands. The *right* trunk receives its afferents from the right atrium and from the right border and diaphragmatic surface of the right ventricle. It runs upwards in the atrioventricular groove, close to the right coronary artery, and then ascends in front of the ascending aorta to terminate in one of the innominate lymph glands, usually to the left of the median plane.

2. The *lymphatic drainage of the lungs and pleuræ.*—The lymph vessels of the lungs originate in two plexuses, a superficial and a deep. The superficial plexus is placed beneath the pulmonary pleura; the deep accompanies the branches of the pulmonary vessels and the ramifications of the bronchi. In the case of the larger bronchi the deep plexus consists of two networks—a submucous, beneath the mucous membrane, and a peribronchial, outside the walls of the bronchi. In the smaller bronchi there is but a single plexus, which extends as far as the bronchioles, but fails to reach the alveoli, in the walls of which there are no traces of lymph vessels. The superficial efferents turn round the borders of the lungs and the margins of their fissures, and converge to end in the bronchopulmonary lymph glands; the deep efferents

are conducted to the hilum along the pulmonary vessels and bronchi, and end, for the most part, in the bronchopulmonary lymph glands. No free anastomosis occurs between the superficial and deep lymph vessels of the lungs, except in the region of the hilum. In the peripheral parts of the lung small connecting channels do exist between the superficial and the deep lymph vessels and, although they are difficult to demonstrate in injected specimens, they are capable of becoming dilated so as to direct the lymph flow from the deep to the superficial vessels, when the outflow from the deep vessels is obstructed by disease of the lung or pulmonary glands. At the bottom of the fissures the lymph vessels of the adjoining lobes communicate with one another, so that although there is a general tendency for the lymph vessels from the upper lobes of the lungs to pass to the superior tracheobronchial lymph glands and for those from the lower lobes to join the inferior tracheobronchial group, these connexions are not exclusive.

The lymph vessels of the pleura consist of two sets—one in the visceral and another in the parietal part of the membrane. Those of the visceral pleura drain into the superficial efferents of the lung, while those of the parietal pleura have three modes of ending, viz.: (*a*) those of the costal portion join the lymph vessels of the internal intercostal muscles and so reach the internal mammary lymph glands; (*b*) those of the diaphragmatic part are drained by the efferents of the diaphragm; while (*c*) those of the mediastinal portion end in the posterior mediastinal lymph glands.

3. The *lymphatic drainage of the thymus.*—The lymph vessels of the thymus end in the innominate, tracheobronchial, and internal mammary lymph glands.

4. The *lymphatic drainage of the œsophagus.*—The lymph vessels of the œsophagus form a plexus round that tube, and the collecting vessels from the plexus drain into the posterior mediastinal lymph glands.

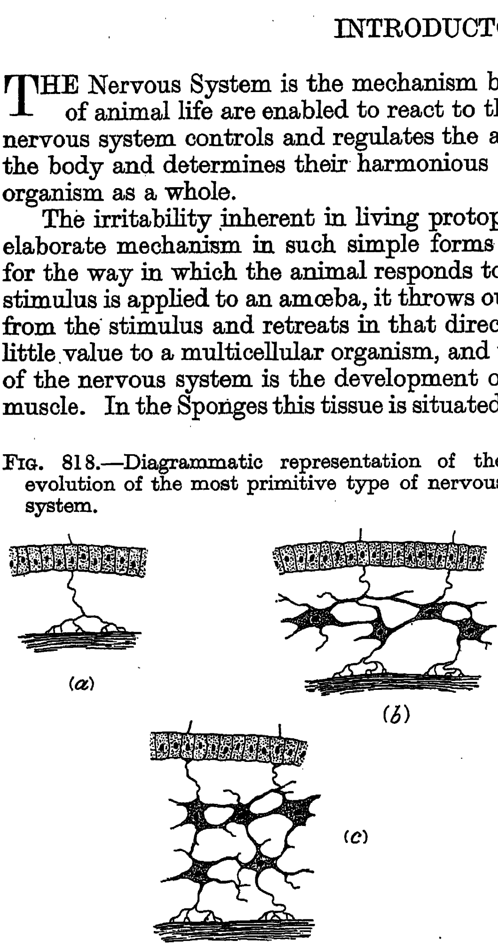
NEUROLOGY

INTRODUCTORY

THE Nervous System is the mechanism by which all, save the lowest, forms of animal life are enabled to react to their environment. In addition, the nervous system controls and regulates the activities of all the other systems of the body and determines their harmonious co-operation, for the benefit of the organism as a whole.

The irritability inherent in living protoplasm obviates the necessity for an elaborate mechanism in such simple forms as the amœba, and is responsible for the way in which the animal responds to stimulation. When a mechanical stimulus is applied to an amœba, it throws out pseudopodia on the side removed from the stimulus and retreats in that direction. Such a reaction would be of little value to a multicellular organism, and the first step towards the evolution of the nervous system is the development of a contractile tissue akin to plain muscle. In the Sponges this tissue is situated close to the surface and it responds to direct stimulation, but this arrangement provides for the possibility of localised movements only. In addition to the development of a contractile tissue (or *effector* apparatus) a mechanism must be developed for the reception of stimuli (*receptor* apparatus) and for their transmission to the whole effector apparatus, before generalised movements, which constitute a notable advance along the path of evolution, can become possible.

FIG. 818.—Diagrammatic representation of the evolution of the most primitive type of nervous system.



The cuticle is developed in order to protect the more delicate vital tissues of the animal against its environment, and it is not surprising to find that some of the ectodermal cells become specialised so as to enable them to appreciate alterations in the environment. The most primitive of these sensory cells possess two processes, of which the one projects from the surface of the cuticle and the other grows inwards to establish contact with the effector (fig. 818, *a*). Many of these primitive sensory cells migrate more deeply into the subcuticular tissues, leaving their peripheral processes in the ectodermal layer, where they may lie free or may arborise around the bodies of other sensory cells (fig. 818, *b*). In Cœlenterata, which exhibit the simplest form of nervous system, sensory cells are scattered over the cuticle and are linked up to a subcuticular ganglion cell plexus, the constituents of which are connected both to the effector apparatus and to one another. Such an arrangement enables a localised stimulus to bring about a generalised response; and, in addition, it provides for the correlation of a number of incoming stimuli and for the co-ordination of the outgoing response (fig. 818, *c*). This diffuse type of nervous system, though admirably adapted to the needs of such an animal as Hydra, whose movements, though generalised, are limited in character, gives way to a centralised arrangement in higher forms, where the motor possibilities are much more numerous and varied.

In the segmented types, the diffuse ganglion cell plexus of the Cœlenterata is separated into an appropriate number of segmental ganglia, which are connected not only to the receptors and effectors of their own segments but also to one another. Incoming stimuli can be distributed and correlated so as to bring about a co-ordinated response affecting a large number of segments and, as a result of the centralisation, the efficiency and the speed of the response are greatly increased.

In these simpler forms of nervous system the response to stimulation is immediate, and the same stimulus, repeated under the same conditions, always provokes the same response. The behavioural reactions of such animals are therefore stereotyped in charater, for they have not acquired the power of inhibition or the ability to register past experience, and plasticity of behaviour is impossible in the absence of these two factors.

With the evolution of vertebrates the nervous system underwent further changes, the most important of which was the development of a suprasegmental controlling centre, namely the brain, already foreshadowed in annelid worms by the large ganglia found in the head region. Owing to the elongated form of the body and the mode of progression, it is the head end of the animal which is subject to the greatest number of afferent impressions, and this number is enormously increased by the development of the olfactory and of the visual apparatus in the same situation. These factors determined the enlargement of the cephalic end of the nervous system, and its further growth followed, in the first place, from the necessity to link up with the rest of the nervous system in order that olfactory, visual and other stimuli received by the brain might be able to produce an effector response involving any part or even the whole of the motor system. The power to delay the immediate localised reactions to local stimuli in any part of the body, in view of contrary stimuli coming from the head region, became urgently necessary in order to allow time for the complete correlation of afferent impressions from all sources. The acquisition of this power of inhibition was an enormous step forward in mental development. The animal ceased, partially at least, to react instantaneously and reflexly to all incoming stimuli, and the interval of time so introduced enabled the ultimate response to take on a purposive character. At this stage in the evolution of the nervous system a localised stimulus may be followed by one of several results. It may produce an immediate, local response, an immediate general response, a delayed response, or the response may be inhibited completely.

The acquisition of the power to register past experience is the last and greatest step forward in mental development, and it has only been rendered possible by additional growth of the brain and the establishment of association areas in the cortex. This new acquisition of the nervous system is well developed in the mammalia, and the higher an animal is in the evolutionary scale the more numerous are its association areas and their connexions. The registration of past experience exerts a very profound influence on behaviour, endowing it with greater plasticity and increasing the complexity of all behavioural reactions. The dominance of man in the animal world is to be attributed to a further elaboration of the association areas, which enables him to benefit not only by his own past experience, but also, through the medium of education, by the past experience of others.

The Functional Components of the Nervous System

The definition of the nervous system which was given at the beginning of this section covers two spheres of activity. It is through the nervous system that an animal is enabled to react to alterations in or to stimuli from its external environment, and it is through the nervous system that all the other systems of the body are governed and controlled, so that their activities are directed towards the good of the animal as a whole. These two components of the nervous system are designated the *somatic* and the *splanchnic* or *visceral components*, and they have much in common. Both components are provided with a series of receptors and of effectors, and the translation of a stimulus

applied to a receptor into an effector response is brought about by the mechanism of the nervous system which has already been outlined.

The **somatic component** deals with the reception, translation and transmission of stimuli which originate in the somatic receptors and result in alterations in the locomotor apparatus of the body. It can be subdivided into an *afferent* or *centripetal* and an *efferent* or *centrifugal* side. The somatic receptors are formed by a series of end-organs, situated in or close to the skin, in the muscles, tendons and joints (p. 1216). The receptors found in or close to the skin receive their stimuli from the external environment. The term *exteroceptive* is applied to the variety of sensibility to which they give rise. Painful, tactile, thermal, pressure, olfactory, visual and auditory stimuli are all exteroceptive in character. The receptors found in the muscles, tendons and joints have their source of stimulation within the body and are independent of the external environment. The variety of sensibility to which they give rise is termed *proprioceptive*. Sensations of movements, both active and passive, and sensations of posture are proprioceptive in character. These constituents of proprioceptive sensibility, like all the constituents of exteroceptive sensibility, succeed in reaching consciousness, on account of the fact that they ultimately reach the cerebral cortex or the thalamus. There are, however, constituents of proprioceptive sensibility which never intrude into consciousness. They are responsible for the muscular adjustments which are constantly necessary during the performance of any movement, however simple.

The *somatic efferent component* includes the effector apparatus of the body and the series of neurones which activate them. It may be brought into play either by the exteroceptive or by the proprioceptive constituents of the somatic afferent component.

The **splanchnic** *component* comprises that portion of the nervous system which regulates and controls the activities of the blood-vessels, the secretory glands and the viscera. Like the somatic component it can be subdivided into an afferent and an efferent side. Special end organs are associated with the reception of stimuli in the walls of the viscera, and the effector apparatus is represented by the glandular epithelial cells and the involuntary muscle of the viscera and the blood-vessels. Under normal conditions the splanchnic component of the nervous system is constantly at work, but its activities are carried out without intruding into consciousness. When all the viscera are working efficiently and harmoniously a characteristic feeling of well-being is experienced. It is uncertain whether this is to be regarded as the appearance in consciousness of the splanchnic afferent component, but, if so, it is necessary to postulate the existence of splanchnic centres in the forebrain, and evidence is accumulating to show that such centres do actually exist (p. 966). That, under abnormal conditions, the activities of the splanchnic component do intrude into consciousness is a matter of everyday observation. The occurrence of pain as a sign of such conditions probably indicates that the neurones constituting the splanchnic afferent component are linked up by means of collaterals with the neurones of the somatic afferent component. Stimuli which give rise to tactile or painful impressions when applied to the skin or subcutaneous tissue do not give rise to similar impressions when applied to the viscera, and yet pathological conditions, especially those leading to increased tension of the muscular walls of viscera, can and do give rise to pain. Whether such visceral pain is due to the passage of painful stimuli along the visceral afferent pathways or whether it is due to the spread of abnormal stimuli from the visceral to the somatic afferent pathways by means of collaterals cannot be decided satisfactorily.

The activities of these two great components of the nervous system are the basis of the conscious life. From the correlation and association of the impulses which stream into the nervous system from the afferent components are built up those sensory combinations which confer the power of controlling behaviour in the light of past experience and constitute the phenomenon of memory. The co-ordinated impulses which pass out along the efferent components and result in positive reactions, or in the inhibition of such reactions, are all dependent on the efferent components and constitute the behaviour of the individual. Behaviour can only manifest itself through the effector

apparatus, and the more it is influenced by past experience the more purposeful does it become. Throughout the whole of evolution there has been a steady increase in the purposive character of behaviour, due to the elaboration of the connexions within a centralised nervous system.

The constituents of the somatic afferent component have been analysed still further. Head and other investigators have examined the effects of sections of peripheral nerves and posterior nerve roots, and the phenomena associated with the return of sensation after division followed by suture, and after crushing without division. As a result of his observations Head divided general sensibility into (*a*) cutaneous and (*b*) deep sensibility, and he further differentiated two varieties of cutaneous sensibility as (1) epicritic and (2) protopathic. *Epicritic sensibility* localises tactile and painful stimuli, differentiates neighbouring degrees of temperature and appreciates very light touch. It is discriminative in quality and is abolished when the post-central gyrus of the cortex is destroyed. *Protopathic sensibility* recognises tactile and painful stimuli, but has no power of localisation and can distinguish between extremes of temperature only. It is not abolished when the cerebral cortex is destroyed, for it can reach consciousness in the thalamus. *Deep sensibility* includes all the varieties of proprioceptive sensibility and, in addition, responds to, and localises, pressure stimuli of all kinds.*

Stopford has analysed deep sensibility into two varieties analogous to the epicritic and protopathic components of cutaneous sensibility. He recognises a finer element, which appreciates sensations of posture, and localises accurately both pressure and pressure pain, and a cruder element which recognises pressure and pressure pain without any power of localisation.

There is, then, in both cutaneous and deep sensibility, a finer, discriminative element which requires for its full appreciation that the cortex of the postcentral gyrus should be intact, and a cruder element which can reach consciousness in the thalamus. These two elements, as will be seen later, travel by different pathways in the spinal cord, and the pathway followed by the cruder element is, as might have been guessed, phylogenetically the older of the two. Kappers has suggested the terms *gnostic* and *vital* for these two elements. Gnostic sensibility is of predominant importance for the intellectual life and vital sensibility for the animal life.

The Structure of the Nervous System

Nerve cells constitute the units of structure in the nervous system. They exhibit a remarkable range of variation, dependent, apparently, on the particular functions with which they are associated, but although they may and do vary in the details of their structure, in size and in shape, they all possess certain features in common. Nerve cells are specialised to enable them to receive and to transmit nervous impulses and, with certain exceptions to be noted later, they are provided with a *cell body*, one or more receiving processes or *dendrites*, and one transmitting process or *axon*. The precise character of a nervous impulse is uncertain, but it possesses many properties which suggest an analogy with an electrical current and, fortunately, for a clear understanding and appreciation of the anatomy of the nervous system definite knowledge on this point is not essential.

The *cell body* or *cyton* is provided with a limiting membrane, which may serve to insulate it from its surroundings. In certain situations, e.g. sympathetic ganglia and the posterior nerve root ganglia of the spinal nerves, the membrane is surrounded by a nucleated capsule (fig. 819), which is structurally continuous with the neurolemma sheath of the axon. The Golgi apparatus, which has been described as a regular feature of many of the cells of the body (p. 2), was first demonstrated in nerve cells. A system of fine intracytoplasmic

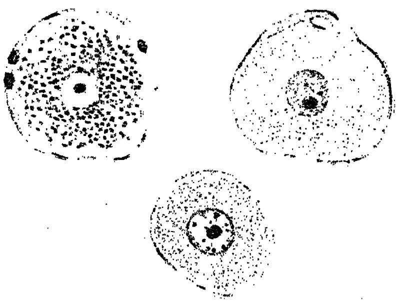
* Many neurologists regard the phenomena associated with the return of sensation as pathological in character, or as dependent on changes which accompany regeneration, but, on the whole, the balance of the available evidence supports the view that there are two distinct elements in general sensibility. For a full discussion of these views and a list of references to the literature, see *Sensation and the Sensory Pathway*, by J. S. B. Stopford, London, 1930.

canals, first described by Holmgren, is present in some ganglion cells.* Two positive features, which are not found elsewhere, serve to differentiate nerve cells from the cells of all other tissues. (1) The presence in the cytoplasm of a number of granules which stain deeply with basic anilin dyes and are known as *Nissl's bodies* or *spindles* (fig. 50). (2) The presence in the cytoplasm of a number of *neurofibrils* (p. 39).

A very important negative feature also helps to differentiate nerve-cells from other cells in the body. Owing to the high degree of specialisation which they have attained nerve-cells have lost the power of reproduction, and as a result the centrosome, which plays such an important part in the process of cell division, is conspicuous by its absence.

The nucleus of the nerve-cell is large and usually spherical in shape, but it presents no differentiating features and is probably concerned with the metabolic processes of the cell and has no direct influence on its special functional activities.

FIG. 819.—Three types of nerve-cells from a spinal ganglion of a cat. Stained with hæmatoxylin and eosin. ×350. (The nuclei of the cells lining the capsule are shown in the left-hand figure only.)



It will be seen, therefore, that apart from the possession of Nissl's bodies and neurofibrils and the loss of the centrosome, the cell body of a nerve-cell does not differ markedly from the cells of other tissues in the body. The processes with which it is provided are, however, in nearly all varieties of nerve-cells, a very striking and characteristic feature. The **dendrites** are characterised by the repeated and irregular manner in which they divide into branches. These branches begin to arise close to the cell body, and their terminal filaments rarely extend beyond its immediate neighbourhood. They are always confined to the grey substance of the nervous system or of the various ganglia. They represent extensions of the cytoplasm of the nerve-cell, and they therefore contain Nissl's bodies in addition to neurofibrils. A large Nissl's body is situated at the *bifurcation cone*, the point of origin of the first branch, and, owing to the reduction in size due to repeated branching, the Nissl's bodies become progressively smaller as the dendrites are traced towards their terminal arborisations. Numerous minute swellings, the significance of which is uncertain, are found studded along the dendrites and their branches.

No difficulty need be experienced in distinguishing the **axon**. The area of the cell body from which it arises forms a slight surface projection, termed the *implantation cone* or *cone of origin*, and is devoid of Nissl's bodies. The neurofibrils converge on the implantation cone and enter the axon, forming practically the whole of its bulk. The axon may give off one or more *collaterals* soon after leaving the cell, but these come off at right angles to its course and are readily distinguished from the branching of a dendrite. The axon is, as a rule, very much longer than the dendrites and may extend as much as 100 cm. from its origin before it breaks up into a terminal arborisation, the form of which depends in part on the function of the parent cell. Where this terminal arborisation is not related to an actual effector it ends in relationship with the dendrites or body of another nerve-cell. In the majority of cases the ends of the axon interlace with the branches of the dendrites of another cell, and this intimate relationship is termed a *synapse*. The structure of the axon and its medullary and neurolemma sheaths is described in detail on pp. 40-42. The neurolemma sheath plays a very important part in the regeneration of nerve-fibres, and it must be noted that those fibres which do not extend beyond the central nervous system are devoid of a neurolemma sheath, although they are usually myelinated. Some of the axons of the grey matter of the brain and spinal cord are entirely naked. They are very fine and threadlike and never extend far from their parent cells. Another variety of nerve-fibre is

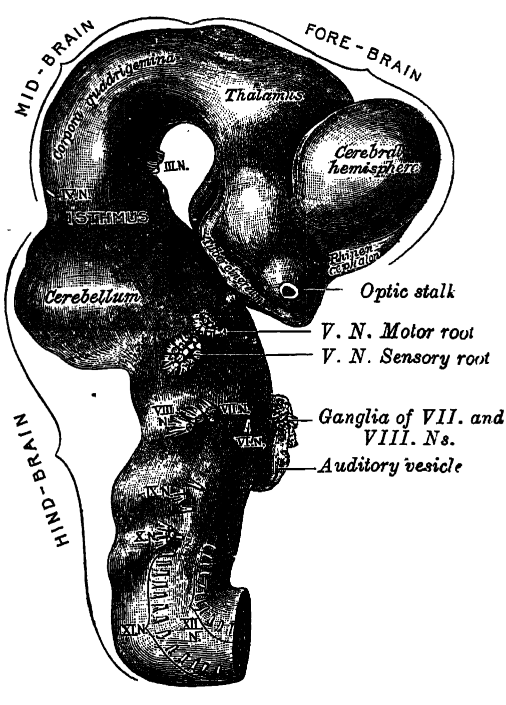
* See footnote on p. 885.

found in the sympathetic system. These axons are unmyelinated but are provided with nucleated neurolemma sheaths (Remak's fibres).

The neurone includes the cell body and all of its processes. Waldeyer's *Neurone Theory* holds that each neurone is an independent unit and that, although nervous impulses pass from one neurone to another at a synaptic junction, there is no structural continuity between them. This view has been attacked from time to time, but it still receives very general support from neurologists. Striking evidence in its favour can be obtained by observing the effects of injury or disease of the cell body. The Nissl's bodies undergo chromatolysis and eventually disappear not only from the cell body but also from the dendrites. The neurofibrils become swollen and hypertrophied at first, and later they break up and may disappear completely, a degenerative process which the dendrites and the axon share with the cell body. These changes, however, are strictly limited to the neurone concerned and do not extend beyond synaptic junctions. Again, section of the axon is followed by degenerative changes, usually of a transient character, in the cell body. They include the fragmentation of the Golgi apparatus and its displacement towards the periphery of the cell.* Each neurone, therefore, can be regarded as an independent structural unit, but functionally neurones are interdependent on one another to a remarkable extent, and every nervous impulse passes through a series of neurones before it reaches the appropriate effector.

It should be observed that two features in the anatomy of the nerve-cell, (1) the profusion of its dendrites and (2) the collaterals given off by its axon, facilitate the correlation and association of afferent impressions and the co-ordination of efferent impulses, which are the essential factors in mental development. By the profusion of the branches of its dendrites the cell is brought into functional relationship with a large number of other cells, and by means of the collaterals given off by its axon the cell is able to discharge its stimuli into a large number of different channels.

Fig. 820.—The brain of a human embryo about 10·2 mm. long. Right lateral aspect. (From a model by His.)



The Parts of the Nervous System

We have seen already (p. 60) that even prior to the closure of the neural tube three primary enlargements occur at its cephalic end. After the closure of the tube these enlargements constitute the three primary cerebral vesicles and, by further development and growth, they give rise to the brain. From the cephalic portion of the *prosencephalon*, or forebrain, two symmetrical diverticula arise during the fourth week of intra-uterine life to form the cerebral hemispheres, and their cavities persist throughout life as the lateral ventricles of the brain. The enormous expansion and thickening which the walls of these two vesicles undergo is characteristic of the mammalia and especially of man, and gives rise to the cortex or pallium and the corpus striatum. Together with the lamina terminalis, the anterior blind

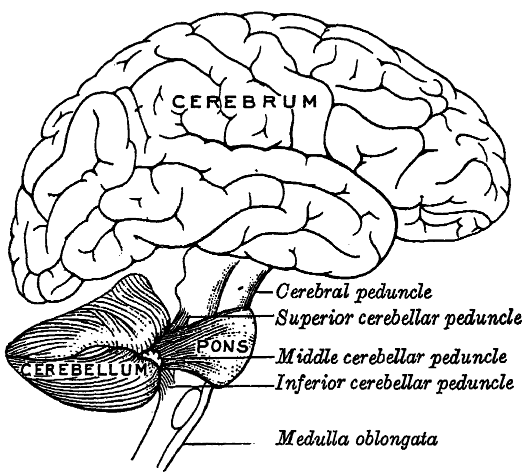
* See a paper by W. G. Penfield, "The Golgi Apparatus and its Relationship to Holmgren's Trophospongium in Nerve-cells," *Anat. Record*, vol. 22.

end of the original tube, which serves to connect them, and certain structures on the base of the brain to be described later, the cerebral hemispheres constitute the *telencephalon*. The caudal part of the prosencephalon constitutes the *diencephalon*. Its lateral walls become greatly thickened and form the thalami, while its cavity, reduced to a deep slit, forms the third ventricle of the brain. The growth of the diencephalon is quite overshadowed by the growth of the cerebral hemispheres, and it becomes completely hidden from surface view. The *mesencephalon*, as contrasted with the prosencephalon and the rhombencephalon, undergoes remarkably few changes. The thickening of its walls reduces its vesicle to a short canal—the aqueduct of the mid-brain—which connects the caudal end of the third to the cranial end of the fourth ventricle.

The *rhombencephalon*, or hind-brain, becomes subdivided into a cephalic portion, termed the *metencephalon*, and a caudal portion, termed the *myelencephalon*. From the lateral walls and floor plate of the cephalic portion the pons is developed, while its originally thin roof plate becomes invaded by the cells of the rhombic lip (p. 112), and converted into the cerebellum. The caudal portion gives rise to the medulla oblongata. The cavity of the vesicle of the hind-brain becomes the fourth ventricle of the brain, communicating in front with the third ventricle through the aqueduct of the mid-brain, and behind with the central canal of the spinal cord.

These derivatives of the three primary cerebral vesicles, viz. the *cerebrum* (telencephalon plus diencephalon), the *mid-brain*, the *pons* and *cerebellum* and the *medulla oblongata*, lie within the cavity of the cranium and together constitute the *brain*.

FIG. 821.—A scheme showing the connexions of the several parts of the brain. (After Schwalbe.)



The remainder of the neural tube gives rise to the *spinal cord*, which still retains a vestige of its original tubular character in its central canal.

The mid-brain, pons and medulla oblongata, connect the cerebrum above, to the spinal cord below, and may be termed collectively the *brain-stem*.

The brain and the spinal cord constitute the *central nervous system*, and are situated in the central axis of the body. The nerves which arise from the brain (twelve pairs of cranial nerves) and from the spinal cord (thirty-one pairs of spinal nerves) together form the *peripheral nervous system*.

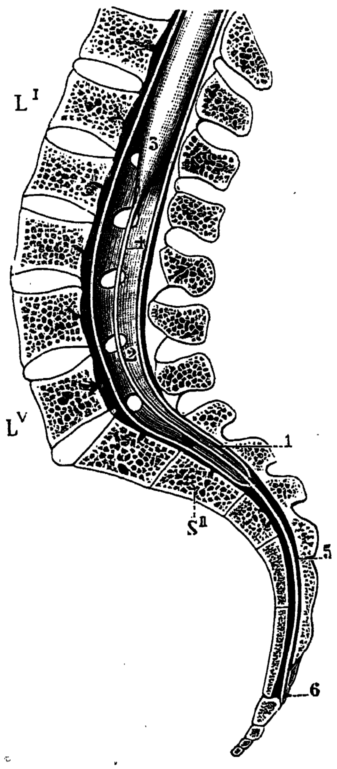
It has already been indicated that the nervous system as a whole is subdivisible into a somatic and a visceral mechanism, and the components of these two mechanisms contribute both to the central and to the peripheral nervous system.

The somatic components of the central and peripheral nervous systems may be grouped together under the term '*cerebro-spinal system*,' in contradistinction to the '*autonomic system*,' which comprises all the components of the visceral mechanism. The autonomic system, however, includes two ganglionated nerve trunks (the sympathetic trunks), which lie on the ventrilateral aspect of the vertebral column extending from the atlas to the coccyx, where these two trunks fuse in an unpaired ganglion (the ganglion impar). These two trunks receive their visceral efferent components from a strictly limited region of the spinal cord which extends from the first (sometimes the second) thoracic to the second or third lumbar segment. Visceral efferent components, however, are distributed directly by certain of the cranial nerves (third, seventh, ninth, tenth and eleventh) and by the second, third and frequently the fourth sacral nerves. It has been found experimentally that the

visceral efferent components of these cranial and sacral nerves are usually functionally antagonistic to the visceral efferent components of the sympathetic trunks, and that they may react differently to certain pharmacological agents. The autonomic system has therefore been divided into two constituent parts, the *sympathetic* and the *parasympathetic*. The former comprises the two ganglionated trunks, and their numerous subsidiary ganglia and their branches. The parasympathetic system comprises the craniosacral outflow of visceral efferent components together with such visceral afferent components as they may convey in addition. Small ganglia, which may be situated on the walls of the viscera concerned, are placed in the course of the efferent parasympathetic fibres.

It is characteristic of the autonomic system that the efferent fibres from the central nervous system do not, like the nerves of the cerebrospinal nervous system, pass direct to the effectors, but terminate in a ganglion where they are relayed. It is customary, therefore, to use the terms 'preganglionic and postganglionic' fibres with reference to the last stages in the path to the visceral effectors. The afferent fibres of the autonomic system, however, are strictly comparable to the afferent fibres of the cerebrospinal system. They traverse the ganglia without interruption and eventually reach the ganglion on the sensory root of a spinal or cranial nerve where their parent cells are situated.

FIG. 822.—A sagittal section through the vertebral canal showing the lower end of the spinal cord and the filum terminale. (Testut.)



LI, LV. First and fifth lumbar vertebræ. SII. Second sacral vertebra. 1. Dura mater. 2. Lower part of tube of dura mater. 3. Lower end of spinal cord. 4. Intradural, and 5, extradural portions of filum terminale. 6. Attachment of filum terminale to first segment of coccyx.

THE CENTRAL NERVOUS SYSTEM

It is now possible to commence the detailed study of the structures which constitute the central nervous system. They include the spinal cord (medulla spinalis), the medulla oblongata, the pons, the cerebellum, the mid-brain and the cerebrum. It will be found convenient to commence with the study of the spinal cord, which represents the simplest and most primitive part of the central nervous system, and, although it contains the terminals of the great efferent pathways, it also contains the origins and early stages of a number of the great afferent pathways.

THE SPINAL CORD

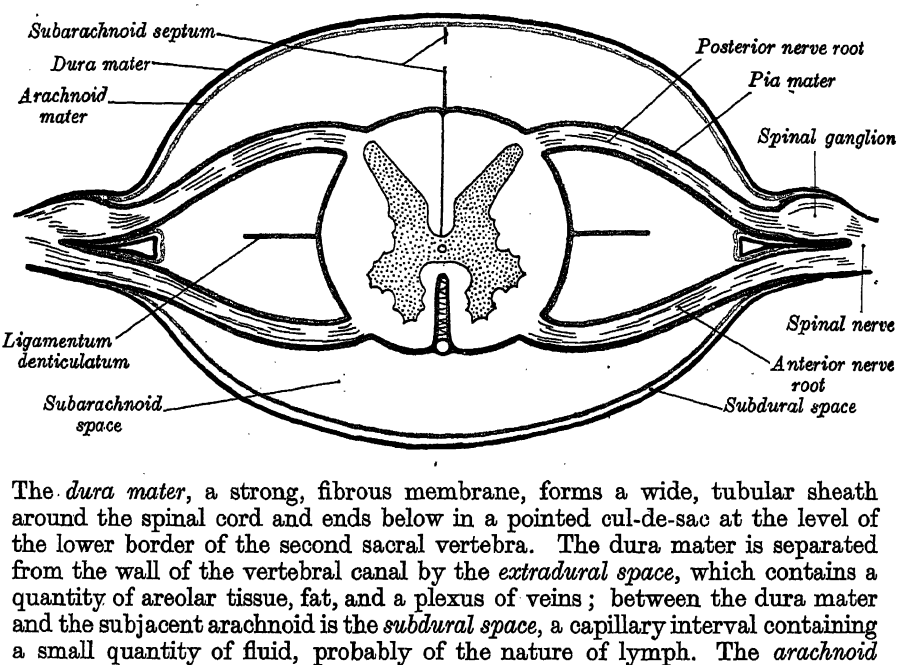
The **spinal cord** [medulla spinalis] is the elongated, nearly cylindrical, part of the central nervous system which occupies the upper two-thirds of the vertebral canal. Its average length in the male is 45 cm.; its weight is about 30 gms. It extends from the level of the upper border of the atlas vertebra to that of the lower border of the first lumbar vertebra, or upper border of the second. Above, it is continuous with the brain; below, it tapers off rapidly into a conical extremity (fig. 824) termed the *conus medullaris*, from the apex of which a delicate non-nervous filament, named the *filum terminale*, descends as far as the first segment of the coccyx (fig. 822).

The position of the spinal cord varies with the movements of the vertebral column, its lower extremity being raised slightly when the column is flexed. It also varies at different periods of life: in early fœtal life the spinal cord is as long as the vertebral canal, but after the embryo has attained a length of

30 mm. the vertebral column begins to grow more rapidly than the spinal cord, and the latter gradually assumes a higher position within the vertebral canal. The chief part of this upward migration occurs during the first half of fœtal life, so that by the twenty-fifth week of fœtal life the lower end of the spinal cord has ascended from the level of the second coccygeal vertebra to that of the third lumbar vertebra, i.e. a distance of nine segments, and there remain but two segments before the adult position is reached (Streeter). In the early embryo the nerve-roots pass transversely outwards to their respective intervertebral foramina, but owing to the relative inequality in the rates of growth of the spinal cord and vertebral column, the nerve-roots become more and more oblique in direction, so that in the adult the lumbar and sacral nerve-roots descend almost vertically to reach their foramina. From the appearance these nerve-roots present at their attachment to the spinal cord and from their great length they are collectively termed the *cauda equina* (fig. 824).

The brain and the spinal cord are ensheathed by three protective membranes separated from each other by spaces. The membranes are named from without inwards the dura mater, the arachnoid mater, and the pia mater (fig. 823).

FIG. 823.—A transverse section through the spinal cord and its membranes. Diagrammatic.



The *dura mater*, a strong, fibrous membrane, forms a wide, tubular sheath around the spinal cord and ends below in a pointed cul-de-sac at the level of the lower border of the second sacral vertebra. The dura mater is separated from the wall of the vertebral canal by the *extradural space*, which contains a quantity of areolar tissue, fat, and a plexus of veins; between the dura mater and the subjacent arachnoid is the *subdural space*, a capillary interval containing a small quantity of fluid, probably of the nature of lymph. The *arachnoid mater* is a thin, transparent sheath which ends at the lower border of the second sacral vertebra; it is separated from the pia mater by the *subarachnoid space*, which contains cerebrospinal fluid. The *pia mater* closely invests the spinal cord and sends some delicate septa into its substance; from each side of the pia mater a fibrous band, named the *ligamentum denticulatum*, projects into the subarachnoid space, and is attached by a series of pointed processes to the inner surface of the dura mater.

A detailed description of these membranes is given on pp. 1023 to 1030.

Thirty-one pairs of spinal nerves spring from the spinal cord, each nerve having an anterior and a posterior root, the latter being distinguished by the presence of an oval swelling, termed the *spinal ganglion*. Each root consists of several bundles of nerve-fibres, and at its attachment extends for some distance along the side of the spinal cord. The pairs of spinal nerves are grouped as follows: cervical 8, thoracic 12, lumbar 5, sacral 5, coccygeal 1, and, for convenience of description the spinal cord is divided into cervical, thoracic, lumbar, and sacral regions, corresponding with the attachments of the different groups of nerves.

Although no trace of transverse segmentation is visible on the surface of the spinal cord, it is convenient to regard it as being built of a series of superimposed *spinal segments* or *neuromeres*, to each of which is attached a pair of spinal nerves.

The *filum terminale* (figs. 824, 825) is a delicate filament, about 20 cm. long, continued downwards from the apex of the conus medullaris. Its upper part, or *filum terminale internum*, about 15 cm. long, is continued within the tubular sheath of dura and arachnoid mater, and reaches as far as the lower border of the second sacral vertebra. It is surrounded by the nerve-roots forming the cauda equina,

FIG. 824.—The cauda equina and filum terminale seen from behind. The dura mater has been opened and spread out, and the arachnoid mater has been removed.

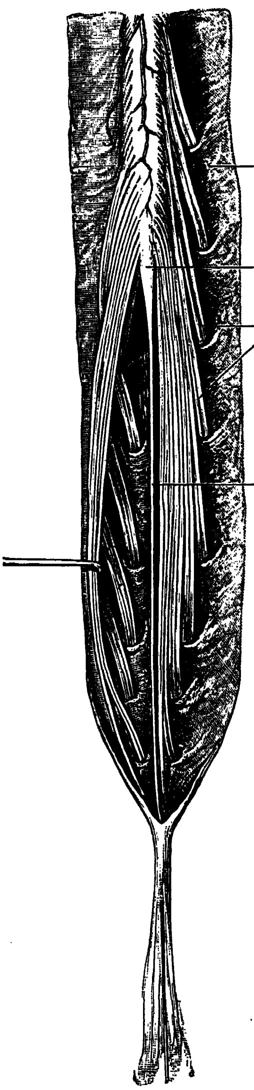
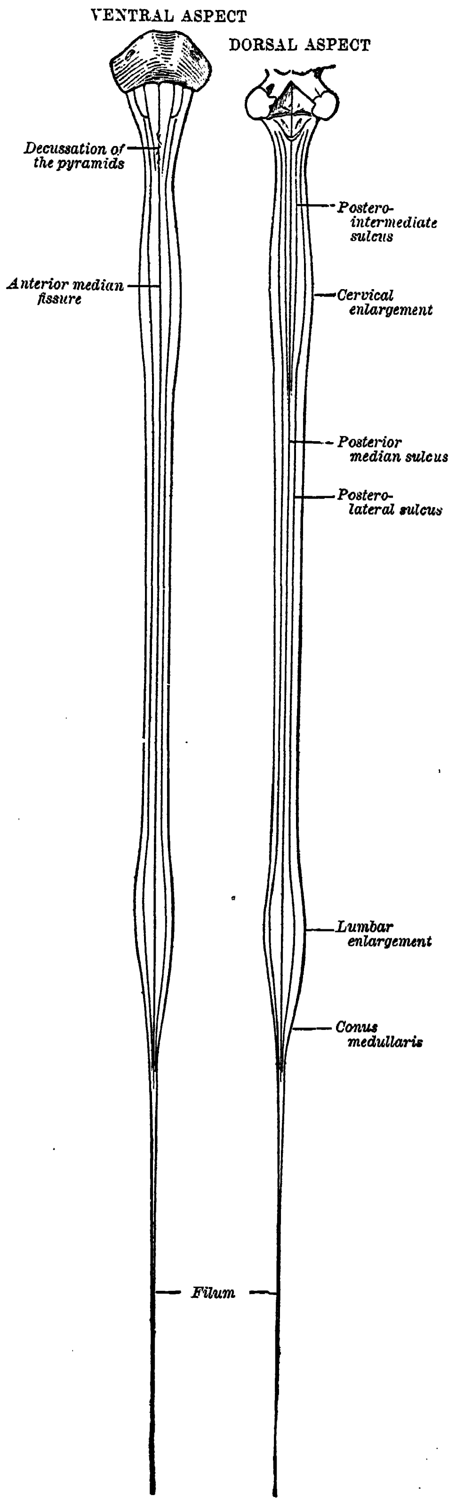


FIG. 825.—Diagrams of the spinal cord.

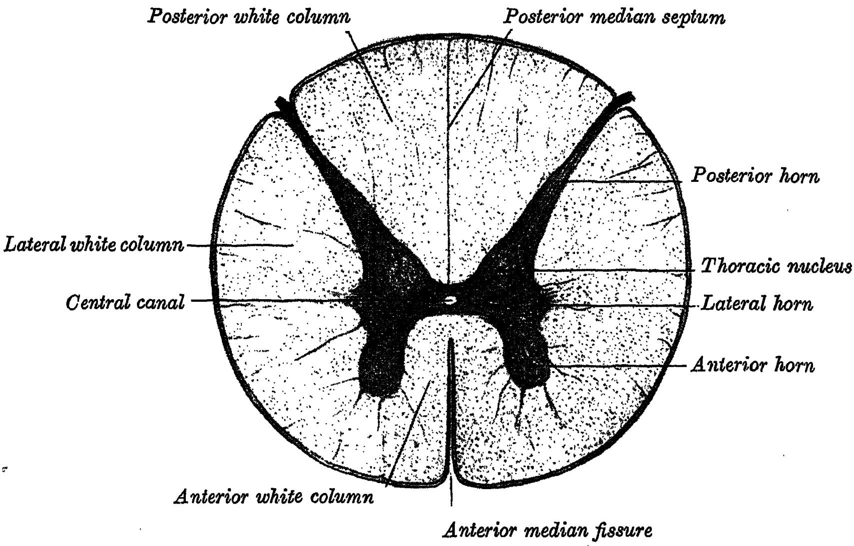


but can be readily distinguished from them by its bluish-white colour. Its lower part, or *filum terminale externum*, is closely invested by, and adherent to, the dura mater ; it descends from the apex of the tubular sheath of dura mater and is attached to the back of the first segment of the coccyx. The filum terminale consists mainly of fibrous tissue, continuous above with that of the pia mater, but adhering to the outer surface of its upper part are a few strands of nerve-fibres which probably represent the nerve-roots of rudimentary second and third coccygeal nerves ; further, the central canal of the spinal cord is continued downwards into it for 5 or 6 cm.

Enlargements.—The spinal cord is not quite cylindrical, being slightly flattened from before backwards ; it also presents two swellings or enlargements, an upper or cervical, and a lower or lumbar (fig. 825).

The *cervical enlargement* is the more pronounced, and corresponds with the attachments of the large nerves of the upper limbs. It extends from the third cervical to the second thoracic vertebra, its maximum circumference (about 38 mm.) being at the level of the roots of the sixth pair of cervical nerves.

FIG. 826.—A transverse section through the mid-thoracic region of the spinal cord. ×8.



The *lumbar enlargement* corresponds with the attachments of the nerves of the lower limbs. It begins at the level of the ninth thoracic vertebra, and reaches its maximum circumference—about 33 mm.—opposite the last thoracic vertebra, below which it tapers rapidly into the conus medullaris.

Fissures and sulci (fig. 826).—An anterior median fissure and a posterior median septum incompletely divide the spinal cord into two symmetrical parts, which are joined across the median plane by a commissural band of nervous matter.

The *anterior median fissure* has an average depth of about 3 mm., but is deepest in the lower part of the spinal cord. It contains a reticulum of pia mater, and its floor is formed by a transverse band of white matter, termed the *anterior white commissure*, which is perforated by blood-vessels on their way to or from the central part of the spinal cord.

The *posterior median sulcus* is very shallow ; from it a septum of neuroglia reaches rather more than half-way into the substance of the spinal cord ; this septum varies in depth from 4 to 6 mm., but diminishes considerably as it is traced downwards.

On each side of the posterior median sulcus, and at a short distance from it, the posterior nerve-roots are attached along a vertical furrow (B.N.A. *posterolateral sulcus*). The portion of the spinal cord which lies between this and the posterior median septum is named the *posterior white column* (posterior

funiculus). In the cervical and upper thoracic regions the surface of this white column presents a longitudinal furrow (B.N.A. *postero-intermediate sulcus*) : this marks the position of a septum which extends into the posterior white column and subdivides it into two fasciculi—a medial, named the *fasciculus gracilis* ; and a lateral, the *fasciculus cuneatus* (fig. 831).

The portion of the spinal cord between the posterolateral sulcus and the anterior median fissure is termed the *anterolateral region.* The anterior nerve-roots, unlike the posterior, are not attached in linear series, and their positions of exit are not marked by a sulcus ; they arise by separate bundles which spring from the anterior grey column and, passing forward through the white matter, emerge over an area of some width. The line of emergence of the most lateral of these bundles is generally taken as the dividing line which separates the anterolateral region into two parts, viz. an *anterior white column,* between the anterior median fissure and the most lateral of the anterior nerve-roots ; and a *lateral white column,* between the exit of these roots and the posterolateral sulcus. In the upper part of the cervical region a series of nerve-roots passes outwards through the lateral white column ; these unite to form the spinal root of the accessory nerve, which ascends and enters the cranial cavity through the foramen magnum (fig. 839), and conveys to the accessory nerve the fibres which supply the Sternomastoid and Trapezius.

Development of the Spinal Cord

Although the development of the spinal cord has been dealt with in a preceding section (pp. 104-108) the following summary will be found useful for a proper appreciation of the internal structure of the adult spinal cord.

The cavity of the neural tube in the region of the spinal cord becomes narrowed down to a dorsiventral slit by the growth of its lateral walls. During the fifth week of development a longitudinal groove, termed the *sulcus limitans,* appears on the inner surface of the lateral wall. This sulcus is the earliest sign of the differentiation of the wall into two functionally distinct areas. The anterior area, or *basal lamina,* contains cells which belong to the efferent pathway and are consequently motor in function ; the posterior area, or *alar lamina,* contains cells which belong to the afferent pathway. The cells in the anterior part of the basal lamina belong to the somatic efferent component, and their axons are distributed to the voluntary musculature of the body. The cells in the dorsal part of the basal lamina belong to the visceral efferent component and their axons, after being relayed in a sympathetic or parasympathetic ganglion, are distributed to the involuntary muscle of the viscera and blood-vessels. In the highest segments of the spinal cord and the hind-brain a third group of cells develops in the basal lamina and lies in an intermediate position between the two groups which have just been described. These cells distribute their axons to the voluntary muscles which develop in association with the visceral or branchial arches (fig. 840).

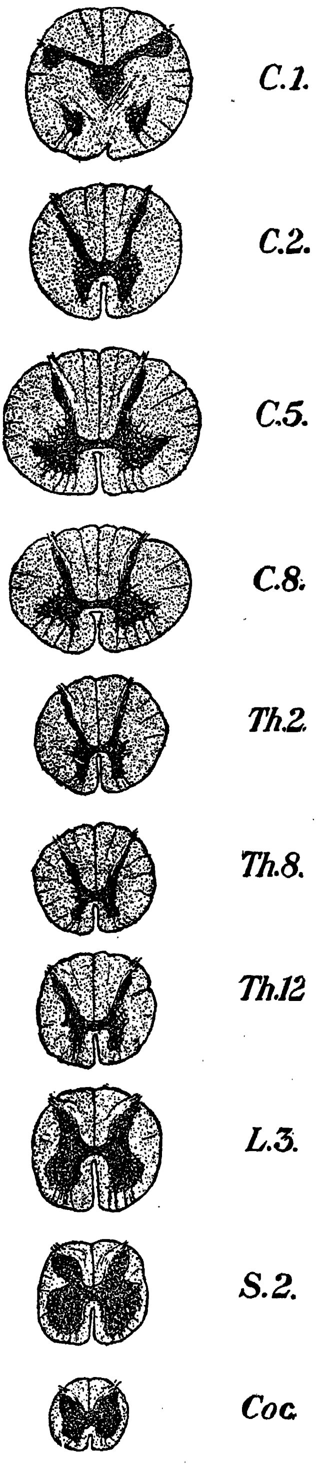
This early functional differentiation of the wall of the neural tube is reflected in the adult spinal cord, for the nerve-cells retain their primitive relationships to a very large extent, as will be seen later.

The character of the lumen of the tube undergoes a striking change during the second and third months of intra-uterine life. Dorsal to the limiting sulcus, the walls become approximated and unite with each other so that the lumen becomes obliterated in its posterior part, while its anterior part persists as a small canal. Incoming fibres from the spinal ganglia collect at first on the dorsilateral aspect of the spinal cord, but as growth proceeds and the grey matter derived from the alar lamina extends in a dorsilateral direction they come to lie at first dorsal to it and finally insinuate themselves between it and the posterior median septum.

While these changes are occurring in the alar lamina and the dorsal half of the spinal cord the cells of the basal lamina are proliferating rapidly, and the grey matter so formed extends in an anterolateral direction. The floor plate at first undergoes little change, so that, as a result of the growth of the adjoining grey matter, a surface elevation is produced on each side of

the median plane anteriorly, and further growth converts the shallow sulcus—which separates them at first—into a deep anterior median fissure (figs. 138, 823). Nerve-cells and nerve-fibres invade the floor plate and constitute the grey and white commissures.

Fig. 827.—Transverse sections through the spinal cord at different levels.



Large efferent tracts grow down from the brain into the lateral and anterior parts of the spinal cord, intervening between the surface and the derivatives of the alar and basal laminæ. Further thickening of these areas is produced by the passage into them of important ascending tracts, whose constituent fibres arise from the cells derived from the alar laminæ.

Internal Structure of the Spinal Cord

The spinal cord is composed of grey and white nervous matter, in both of which there is a supporting framework of neuroglia.

The **grey matter** [substantia grisea] is situated centrally and has the form of a fluted column which runs through its whole length. On transverse section of the spinal cord this column is seen to consist of right and left symmetrical portions connected by a transverse commissure of grey matter, the whole bearing a resemblance to the letter H. The transverse grey commissure is traversed by the central canal, which is just visible to the naked eye. Each lateral portion is shaped like a crescent with its concavity directed laterally, and, as seen on transverse section, can be divided into anterior and posterior horns * according to their relation to the transverse grey commissure.

The **anterior horn** is directed forwards and somewhat laterally. It is short but broad in proportion and fails to reach the surface of the spinal cord, from which it is separated by the anterior white column. The posterior part of the anterior horn is termed the *base*, and the anterior part the *head*, but they are not separated from each other by any definite constriction.

The **posterior horn** is directed backwards and somewhat laterally. It is long and slender, and reaches almost as far as the posterolateral sulcus, from which it is separated by a thin coating of white matter, named the *posterolateral tract*. It consists of a *base*, which is continuous with the base of the anterior horn, a constricted *neck*, and an oval or fusiform *head*, the *apex* of which is capped by a mass of translucent nervous tissue, termed the *substantia gelatinosa*. This gelatinous substance is V-shaped or crescentic in transverse section, and contains both neuroglia and nerve-cells.

A pointed projection from the lateral surface of the grey matter opposite the transverse commissure

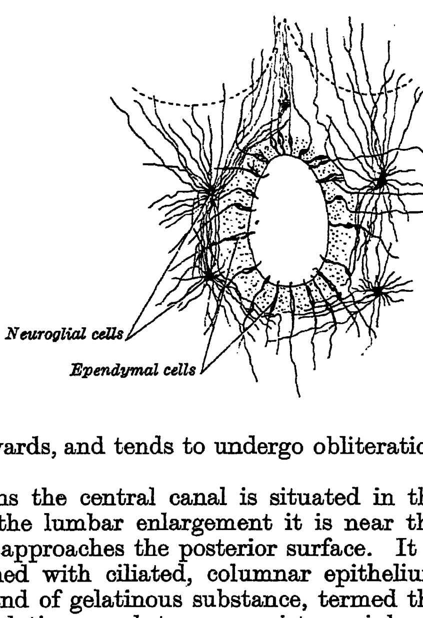
* It should be observed that the terms 'anterior horn,' 'posterior horn' and 'lateral horn' are used only with reference to transverse sections of the spinal cord. When the grey matter of the spinal cord as a whole is under consideration, the terms 'anterior grey column,' 'posterior grey column' and 'lateral grey column' are employed.

constitutes the **lateral horn**. It is easily recognisable in transverse sections through the thoracic and first lumbar segments of the spinal cord, but not elsewhere.

The limits of the grey matter are, as a rule, clearly defined, but in the cervical region strands of grey matter extend into the lateral white column, where they form a network, termed the *formatio reticularis*, opposite the base of the posterior horn. Traces of this reticular formation can be seen also in lower segments.

The quantity of grey matter and the form it presents on transverse section vary at different levels. In the thoracic region the grey matter is small in amount, not only absolutely but relatively to the surrounding white matter. In the cervical and lumbar enlargements, to which the nerves of the limbs are attached, it is greatly increased; so that in the latter, and especially in the conus medullaris, its proportion to the white matter is greater than elsewhere (fig. 829). In the cervical region the posterior horn is comparatively narrow, while the anterior horn is broad and expanded; in the thoracic region, the anterior and posterior horns are narrow, and the lateral horn is evident; in the lumbar enlargement the anterior and posterior horns are both broad; while in the conus medullaris the grey matter assumes the form of two oval masses, one in each half of the spinal cord, connected together by a broad grey commissure. The motor nerves to the limbs arise from groups of nerve-cells which occupy the lateral parts of the broad anterior grey columns in the cervical and lumbar enlargements.

Fig. 828.—A transverse section through the central canal of the spinal cord, showing the ependymal and neuroglial cells. (Lenhossék.)



The **central canal** traverses the entire length of the spinal cord. It is continued upwards through the lower part of the medulla oblongata and opens into the fourth ventricle of the brain; below, it reaches for a short distance (5·6 cm.) into the filum terminale. In the lower part of the conus medullaris it exhibits a fusiform dilatation (the *terminal ventricle*), which has a vertical measurement of from 8 to 10 mm., is triangular on cross section with its base directed forwards, and tends to undergo obliteration after the age of forty years.

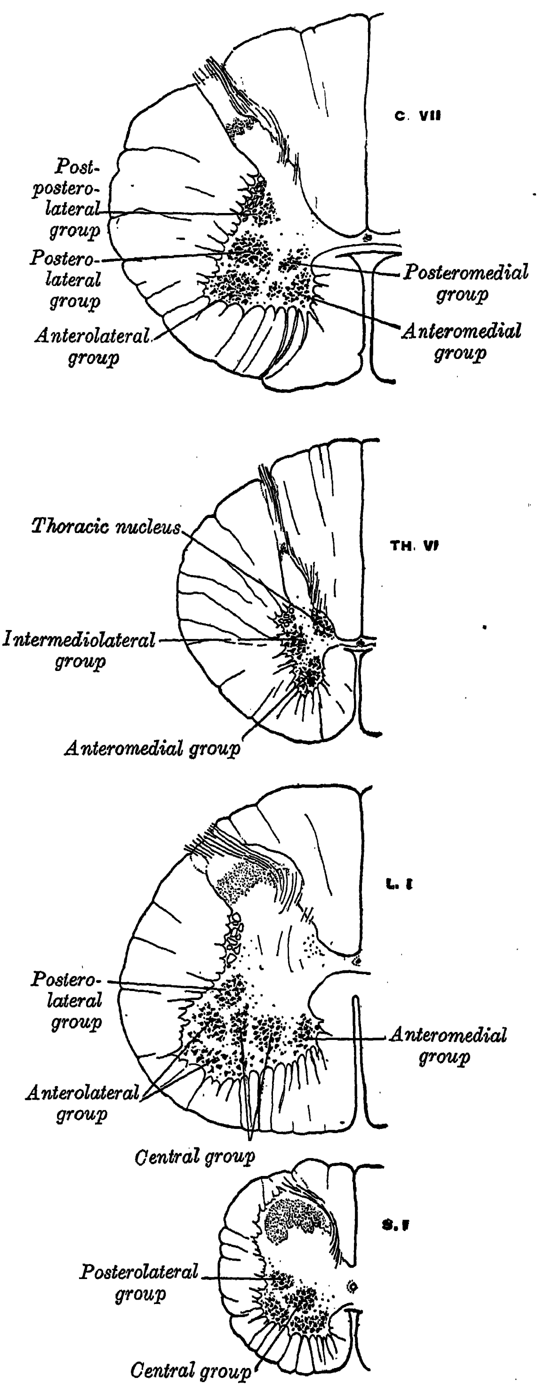
In the cervical and thoracic regions the central canal is situated in the anterior part of the spinal cord: in the lumbar enlargement it is near the middle, and in the conus medullaris it approaches the posterior surface. It is filled with cerebrospinal fluid, and lined with ciliated, columnar epithelium (*ependyma*), which is encircled by a band of gelatinous substance, termed the *substantia gelatinosa centralis*. This gelatinous substance consists mainly of neuroglia, but contains a few nerve-cells and nerve-fibres; it is traversed by processes from the deep ends of the columnar cells which line the central canal (fig. 828).

The grey matter surrounding the canal is named the *grey commissure*. The part in front of the canal is thin, and in contact with the white commissure: it contains a pair of longitudinal veins, one on each side of the median plane. The part behind the canal reaches from the central canal to the posterior median septum; it is thinnest in the thoracic region, and thickest in the conus medullaris.

The structure of the grey matter.—The grey matter of the spinal cord consists of neuroglia, nerve-cells, and nerve-fibres. Throughout the greater part of it the neuroglia is arranged in the form of a sponge-like network, but around the central canal and on the apices of the posterior horns it is condensed to form the gelatinous substance already referred to. The nerve-cells are multipolar, and vary greatly in size and shape, but they may be classified in four main types: (1) Motor cells of large size are found in the anterior grey

column throughout the whole length of the spinal cord. Their axons enter the anterior nerve-roots of the spinal nerves and are distributed to the voluntary musculature. Before leaving the spinal cord they frequently give off collaterals which re-enter and ramify in the grey matter. These large cells are derived from the ventral part of the basal lamina. (2) Motor cells of smaller size are found throughout the lateral grey column. Their axons join the anterior nerve-roots, but they are destined for a sympathetic ganglion where they are relayed to the visceral musculature. (3) Smaller cells, belonging to Golgi's type I, are found throughout the posterior grey column. Their axons, on reaching the white matter, may ascend to higher levels in the spinal cord or may reach the brain; or, they may descend to lower segments of the spinal cord: or, they may divide dichotomously into ascending and descending branches. (4) A few of the small cells found in the posterior grey column and the substantia gelatinosa belong to Golgi's type II. Their axons, therefore, do not leave the grey matter, and are usually short and confined to one segment (intrasegmental neurones). Most of these neurones are confined to one side of the spinal cord. Those whose axons terminate in the grey matter at higher or lower levels constitute *intersegmental neurones*, and serve to link up the different parts of the spinal cord to one another. Some of the axons traverse the white commissure and terminate in the grey matter of the opposite side. They are termed *crossed commissural fibres*.

Fig. 829.—Transverse sections through the spinal cord at different levels, showing the arrangement of the principal cell-columns.



Most of the nerve-cells are arranged in longitudinal columns, and they therefore appear as groups on transverse section (fig. 829).

Nerve-cells in the anterior grey column.—The nerve-cells in the anterior grey column are arranged in columns of varying length. The longest of them occupies the anteromedial portion of the anterior grey column, and constitutes in transverse sections the *anteromedial group* of the anterior horn. It extends

from the first cervical to the fourth lumbar segments and reappears again in the third and fourth sacral segments, being at its widest in the fourth and fifth cervical segments. A second collection of cells, named the *posteromedial group*, is present in the sixth and seventh cervical and absent from the succeeding two segments, and thereafter extends from the second thoracic to the first lumbar segment, lying immediately posterior to the anteromedial group. There is strong presumptive evidence, from the position and extent of these two columns, for supposing that they innervate the muscles of the trunk, and that the enlargement of the anteromedial group in the fourth and fifth cervical segments indicates the cells of origin of the phrenic nerve.

The other cell-groups in the anterior grey column are more localised and are found in the upper cervical region, and in the cervical and lumbar enlargements. A group of cells is found in the first, second and third cervical segments, lying to the lateral side of the anteromedial group and somewhat dorsal to it. These cells send their axons through the lateral white column to emerge midway between the anterior and posterior nerve-roots, where they constitute the spinal root of the accessory nerve. This group of cells probably represents the branchial (special visceral) efferent group in the basal lamina (fig. 840).

Both in the cervical and in the lumbar enlargements the anterior grey column widens out in a lateral direction, and contains groups of cells which have been classified as anterolateral, posterolateral, post-posterolateral and central. The *anterolateral group* does not extend into the first thoracic or third sacral segments, while the post-posterolateral group is only found in the eighth cervical, first thoracic and the upper three sacral segments. The central group is not present as a separate entity in the cervical enlargement, but it is present from the second lumbar down to the upper part of the second sacral segment.

The functional significance of these cell-groups is difficult to determine. It is possible that the definition of anterolateral and posterolateral groups may be associated with the primitive arrangement of the musculature of the limbs into ventral or flexor and dorsal or extensor groups.

The motor cells in the anterior grey column constitute the last neurone in the efferent pathway. Through their numerous dendrites they receive nerve impulses from a variety of sources and transmit them to the effectors, which are, in this way and at different times, brought under the control of the cerebral cortex, the cerebellum, the corpus striatum, the vestibular apparatus, etc. But the motor cells of the anterior grey column exercise a special influence of their own over the muscular apparatus apart altogether from the stimuli which they merely transmit. Destruction of the motor cells, or the division of their axons, is followed by the phenomena of muscular degeneration, *phenomena which do not result from any other lesion or combination of lesions of the nervous system*. Destruction of the great efferent pathway from the brain will cause paralysis and, after a period, atrophy of the muscle fibres, but the muscle retains its peculiar structure. This variety of control exerted by the nerve-cells of the anterior grey column is referred to as *idiodynamic control*. It must be remembered, however, that these cells, when cut off from all other sources of stimulation, are not themselves able to generate impulses which throw the effector into a state of contraction.

For local reflexes the anterior column cells stand in connexion with posterior column cells of the same segment, and the constant stream of impulses which they receive from this source is responsible for the reflex activity of muscle fibres and for their normal myotonus. Section of the posterior nerve-roots interrupts the intrasegmental reflex arc and, therefore, abolishes both these forms of activity.

Volitional control is exercised by the cerebrospinal (pyramidal) tract acting through the dendrites of the cells in the anterior grey column. But in order that the muscles may respond rapidly and effectively to volitional control they must be in a state of ' ideal tonus,' and this condition is brought about by the influence of the cerebrospinal tract. Destruction of this great motor pathway results, therefore, not only in the paralysis of all volitional movement but also in hypertonicity of the affected muscles. This increase in muscle tonus is due to the loss of the inhibitory control exercised by the cortex. Spasticity of a paralysed limb is characteristic of an upper motor neurone lesion.

Synergic control is exercised by the cerebellum and is essential for co-ordination of different muscles and muscle groups during the performance of volitional movements. The efferent pathway from the cerebellum passes to the red nucleus in the mid-brain and

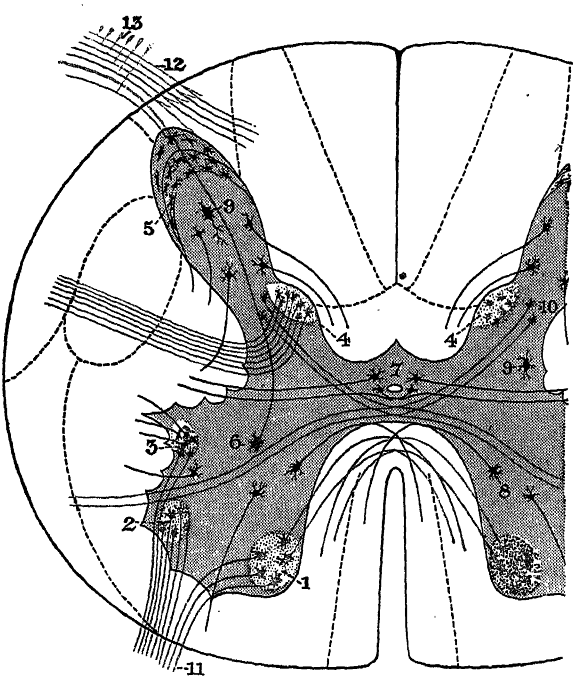
then travels by the rubrospinal tract to the cells in the anterior grey column. The interruption of this pathway leads to muscular incoordination during the performance of voluntary movements, which are then carried out in a jerky and exaggerated manner.

The corpus striatum may possibly exercise control over automatic associated movements (p. 1013); its efferent pathway runs through the red nucleus and the rubrospinal tract. In some cases of hemiplegia, a patient, paralysed in the upper and lower limbs of the same side so far as volitional control is concerned, may, especially on yawning when waking from sleep, stretch both arms above his head. This movement is carried out unconsciously and always in association with the limb of the opposite side; it has been explained as an automatic associated movement inaugurated by the corpus striatum.

The vestibular apparatus controls unconscious equilibratory movements. The efferent pathway runs direct from the lateral nucleus of the vestibular nerve to the cells in the anterior grey column in the vestibulospinal tract.

Nerve-cells in the lateral grey column.—The cells in this column constitute a single group, named the *intermediolateral group*. It extends from the first

Fig. 830.—A scheme showing the mode of distribution of the nerve-cells in the grey matter. (Testut.)



1, 2. Medial and lateral groups of nerve-cells in anterior horn. 3. Nerve-cells in lateral horn 4, 4. Thoracic nucleus. 5. Groups of nerve-cells in substantia gelatinosa. 6. Nerve-cell of anterior horn, the axon of which is passing into the posterior nerve-root. 7. Cells of substantia gelatinosa centralis. 8. Solitary cell. 9. Cells of Golgi. 10. Cells of origin of the anterior spino-cerebellar tract. 11. Anterior root. 12. Posterior root. 13. Spinal ganglion.

thoracic to the first lumbar segment and reappears again in the second, third and fourth sacral segments. In the longer upper part of its extent this cell-group is responsible for the surface projection of the lateral grey column, and its axons pass out in the anterior nerve-roots, and traverse the white rami communicantes to reach the sympathetic gangliated trunk. Finally they are distributed to glands and cardiac or unstriped muscle. In the sacral part of its extent this cell-group is overshadowed by the large posterolateral group and so produces no surface projection. Its axons traverse the anterior nerve-roots and anterior primary rami of the corresponding sacral nerves and eventually constitute the 'pelvic splanchnic nerves' (p. 1138), which represent the sacral contribution to the parasympathetic system.

It should be remembered that this cell-group is a derivative of the dorsal part of the basal lamina (fig. 840), and it retains the same relative position in the adult.

Nerve-cells in the posterior grey column.—1. The *thoracic nucleus* (nucleus dorsalis) occupies the medial part of the base of the posterior grey column, and appears on transverse section as a well-defined oval area (figs. 829, 830). It begins below at the level of the first or second lumbar nerve, and reaches its maximum size opposite the twelfth thoracic nerve. It diminishes in size above the level of the ninth thoracic nerve, and ends opposite the last cervical or first thoracic nerve. Its cells are of medium size, and oval or pyriform in shape; most of their axons pass into the peripheral part of the lateral white column of the same side, and there ascend, under the name of the *posterior spino-cerebellar tract*; a few cross to the opposite side and ascend in the *anterior spino-cerebellar tract*. In the upper cervical region, and again in the middle and lower sacral regions, the posteromedial part of the base of the posterior grey column is occupied by a group of small cells. These two groups are known as the *cervical* and *sacral nuclei*, but, although they occupy the same relative position as the thoracic nucleus, the structure of their cells and the arrangement of the Nissl's bodies show little in common with it, and apparently no close functional relationship exists between them.

2. *Nerve-cells in the substantia gelatinosa.*—These are arranged in three zones: a posterior or marginal, of triangular or fusiform cells; an intermediate, of small fusiform cells; and an anterior, of star-shaped cells. The axons of these cells pass into the lateral and posterior white columns, and there pursue a vertical course. Some of the cells in the anterior zone belong to Golgi's type II, their short axons being confined to the grey matter.

3. *Solitary cells* of varying form and size are scattered throughout the posterior grey column. Some of these are grouped to form an ill-defined *posterior basal column*, lateral to the thoracic nucleus. The axons of the cells of this column pass partly to the posterior and lateral white columns of the same side, and partly through the white commissure to the lateral white column of the opposite side. Before leaving the grey matter, a considerable number run longitudinally for a varying distance in the head of the posterior grey column, forming what is termed the *longitudinal fasciculus* of the posterior column.

A few star-shaped or fusiform nerve-cells of varying size are found in the substantia gelatinosa centralis. Their axons pass into the lateral white column of the same, or of the opposite, side.

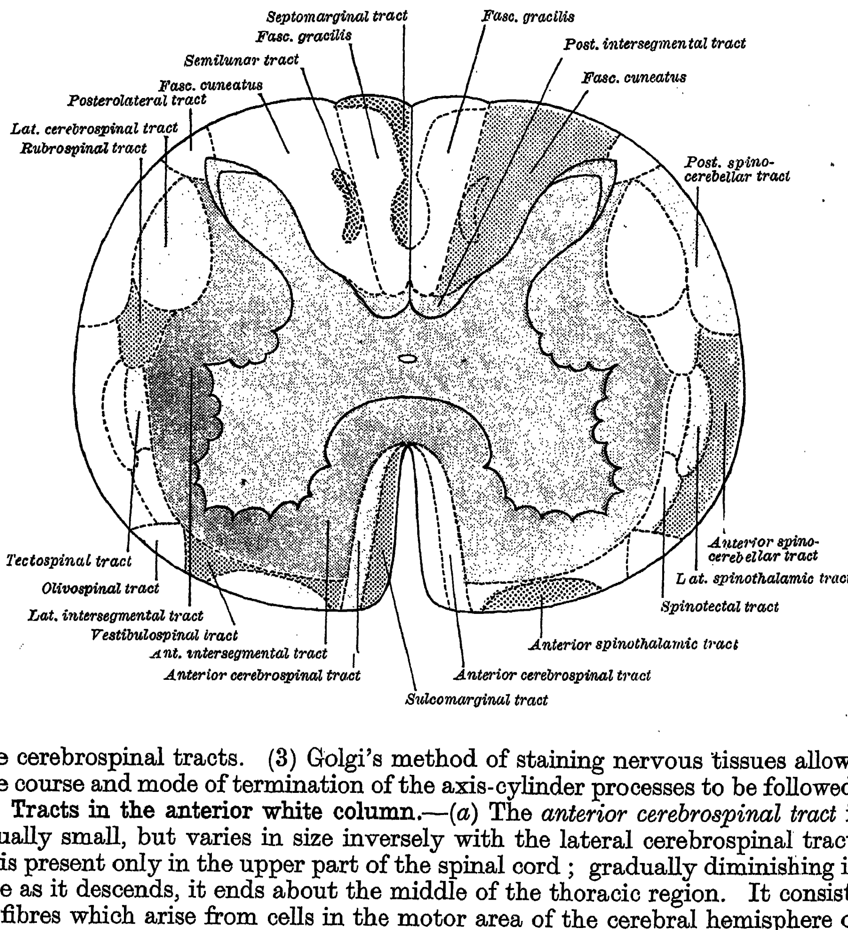
The nerve-fibres in the grey matter form a dense interlacement among the nerve-cells. This interlacement is formed partly of axons which pass from the cells in the grey matter to enter the white columns or the anterior nerve-roots; partly of the axons of Golgi's cells type II, which ramify only in the grey matter; and partly of collaterals from the nerve-fibres in the white columns, which, as already stated, enter the grey matter and ramify within it.

The **white matter** [substantia alba] of the spinal cord surrounds the grey matter, and consists chiefly of medullated nerve-fibres. The nerve-fibres are arranged in three white columns: anterior, lateral, and posterior. The anterior white column lies between the anterior median fissure and the most lateral of the anterior nerve-roots; the lateral, between these nerve-roots and the postero-lateral sulcus; and the posterior, between the posterolateral sulcus and the posterior median septum (fig. 831). The nerve-fibres vary in thickness; the thinnest are found in the fasciculus gracilis, the posterolateral tract (p. 901), and the central part of the lateral white column; the thickest are situated in the anterior white column, and in the peripheral part of the lateral white column. Some of the nerve-fibres run more or less transversely, as for example those which cross the median plane in the white commissure, but the majority pursue a longitudinal course and are divisible into (1) those connecting the spinal cord with the brain and conveying impulses to or from the latter, and (2) those which are confined to the spinal cord, and link together its different segments (i.e. intersegmental or association fibres).

Nerve-fasciculi or tracts.—The longitudinal fibres are grouped into more or less definite bundles or tracts. These are not recognisable from one another in the natural state, for the individual tracts are not surrounded by special sheaths, and their identity has been established by the following methods. (1) A. Waller discovered that if a bundle of nerve-fibres is cut, the portions of the fibres which are separated from their cells rapidly degenerate and become

atrophied. This is known as *Wallerian degeneration.** Similarly, if a group of nerve-cells is destroyed, the fibres arising from them undergo degeneration. Thus, if the motor cells of the cerebral cortex are destroyed, or if the fibres arising from these cells are severed, a *descending degeneration* from the seat of injury takes place in the fibres. In the same manner, if a spinal ganglion is destroyed, or the fibres which pass from it into the spinal cord be cut, an *ascending degeneration* occurs in these fibres above the lesion. (2) In the early stages of the development of the nervous system, the nerve-fibres are naked axis-cylinders ; groups of nerve-fibres acquire their medullary sheaths at different periods ; hence the fibres can be grouped according to the dates at which they receive these sheaths. The first fibres to acquire medullary sheaths are those of the nerve-roots and of the intersegmental tracts, the last, those of

FIG. 831.—A diagram of the principal tracts of the white matter of the spinal cord.



the cerebrospinal tracts. (3) Golgi's method of staining nervous tissues allows the course and mode of termination of the axis-cylinder processes to be followed.

Tracts in the anterior white column.—(*a*) The *anterior cerebrospinal tract* is usually small, but varies in size inversely with the lateral cerebrospinal tract. It is present only in the upper part of the spinal cord ; gradually diminishing in size as it descends, it ends about the middle of the thoracic region. It consists of fibres which arise from cells in the motor area of the cerebral hemisphere of the same side, and which, as they run downwards in the spinal cord, cross in succession through the white commissure to the opposite side, where they end by arborising around the motor cells in the anterior grey column. This tract is found only in man and in the anthropoid apes, but its precise significance is unknown.

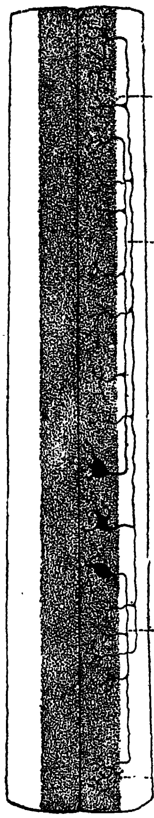
(*b*) The *vestibulospinal tract*, which is derived from the large cells of the lateral vestibular nucleus (p. 922), descends in the anterior white column ;

* Somewhat later a change, termed *chromatolysis*, takes place in the nerve-cells, and consists of the breaking down and ultimate disappearance of the Nissl's bodies. The cell-body swells, the nucleus is displaced towards the periphery of the cell, and the part of the axon still attached to the altered cell diminishes in size and atrophies. Under favourable conditions the cell may resume its normal appearance, and its axon may grow again.

its fibres end around the cells in the anterior grey column. This fasciculus is uncrossed and brings the anterior column cells under the control of the vestibular nuclei of the same side, serving as the efferent path for equilibratory control.

(c) The *anterior spinothalamic tract* is described here as one of the ascending pathways in the anterior white column, although the evidence in favour of its existence as a separate entity is not completely convincing. It has been suggested that it constitutes a pathway for the coarser elements of tactile sensibility, as distinguished from tactile discrimination (p. 883); its fibres are described as arising from cells in the posterior grey column of the opposite side of the spinal cord, ascend in the posterior white column for two or three segments and then cross in the white commissure to reach the anterior white column, in which they ascend to the thalamus.

Fig. 832.—A diagram showing in longitudinal section the intersegmental neurons of the spinal cord. The grey and white parts correspond respectively to the grey and white matter of the spinal cord. (Poirier.)



(d) A small *sulcomarginal tract** adjoins the anterior median fissure.

The remaining fibres of the anterior white column constitute the *anterior intersegmental tract* (fasciculus proprius anterior). It consists of longitudinal intersegmental fibres which arise from cells in the grey matter, and, after a longer or shorter course, re-enter the grey matter. Some of the fibres of this tract pass upwards into the medial longitudinal bundle (p. 949).

Tracts in the lateral white column.—1. Descending tracts.

(a) The *lateral cerebrospinal tract* (crossed pyramidal tract) extends throughout nearly the whole length of the spinal cord; it gradually diminishes in size as it descends, and ends about the level of the attachment of the third or fourth sacral nerves. On transverse section it appears as an oval area in front of the posterior horn and medial to the posterior spinocerebellar tract; in the lumbar and sacral regions, where the posterior spinocerebellar tract is absent, the lateral cerebrospinal tract reaches the surface of the spinal cord. Its fibres arise from cells in the motor area of the cerebral hemisphere of the opposite side. They pass downwards in company with those of the anterior cerebrospinal tract, but cross to the opposite side in the medulla oblongata and descend in the lateral white column of the spinal cord; they end by arborising around the motor cells in the anterior grey column.†

The anterior and lateral cerebrospinal tracts constitute the motor pathway of the spinal cord and have their origins in the motor cells of the cerebral cortex. They descend through the internal capsule of the cerebrum, traverse the cerebral peduncle and pons, and enter the pyramid of the medulla oblongata. In the lower part of the pyramid about two-thirds of them cross the median plane and run downwards in the lateral white column as the lateral cerebrospinal tract while the remaining fibres do not cross, but are continued into the same side of the spinal cord, where they form the anterior cerebrospinal tract. Fibres

* According to some authorities this tract is formed by the crossed fibres of the tectospinal pathway (p. 900).

† Sir E. Sharpey-Schafer (*Proc. Physiological Soc.* 1899) says it is probable that the fibres of the anterior and lateral cerebrospinal tracts are not directly related with the cells of the anterior grey column, but terminate by arborising round the cells at the base of the posterior grey column, which in turn link them to the motor cells in the anterior column, usually of several segments of the spinal cord. In consequence of these interposed neurons the fibres of the cerebrospinal tracts correspond, not to individual muscles, but to associated groups of muscles.

of this tract cross in succession through the white commissure, and thus, generally speaking, all the motor fibres from one side of the brain reach the opposite side of the spinal cord. The proportion of fibres which cross in the medulla oblongata is not a constant one, and thus the anterior and lateral cerebrospinal tracts vary inversely in size. Sometimes the former is absent, and it is then presumed that complete decussation of the motor fibres has occurred in the medulla oblongata. There is experimental and clinical evidence to show that the lateral cerebrospinal tract contains a few fibres which are derived from the cerebral hemisphere of the same side (*uncrossed lateral cerebrospinal fibres*).

(*b*) The *rubrospinal tract* is anterior to the lateral cerebrospinal tract, and on transverse section appears as a somewhat triangular area. Its fibres descend from the mid-brain, where they have their origins in the cells of the red nucleus of the tegmentum of the opposite side ; they end by forming synapses with the cells in the anterior grey column. Through this tract the cells of the anterior grey column are brought under the control of the cerebellum and the corpus striatum. The former exercises synergic control, while the latter may possibly be associated with the control of automatic associated movements (p. 1013).

(*c*) The *tectospinal tract* is anterior to the rubrospinal tract ; its fibres originate in the superior quadrigeminal body of the opposite side,* and end by forming synapses with the cells in the anterior grey column. This tract provides the efferent pathway for visual reflexes.

(*d*) The *olivospinal tract* arises in the vicinity of the olivary nucleus (inferior olivary nucleus) in the medulla oblongata and is seen only in the cervical region of the spinal cord, where it forms a small triangular area at the periphery, close to the most lateral of the anterior nerve-roots. Its fibres form synapses with the cells in the anterior grey column. The functional significance of this tract is unknown, and, in view of the uncertainty which exists with regard to its precise origin in the medulla oblongata, it is frequently termed the *bulbospinal tract*.

2. **Ascending tracts.**—(*a*) The *posterior spino-cerebellar tract* is a flattened band situated at the periphery of the posterior portion of the lateral white column ; medially it is in contact with the lateral cerebrospinal tract ; behind, with the posterolateral tract. It begins about the level of the second or third lumbar nerve, increases in size as it ascends, and finally passes to the cerebellum through the inferior cerebellar peduncle. Its fibres are the axons of the cells of the thoracic nucleus of the same side.

(*b*) The *anterior spino-cerebellar tract*, as seen on transverse section, is a crescentic, flattened tract which occupies the periphery of the lateral white column, in front of the area occupied by the posterior spino-cerebellar tract. Its constituent fibres arise in the cells of the thoracic nucleus and of the adjoining part of the posterior grey column, both from the same and from the opposite half of the spinal cord. The tract commences in the upper lumbar region and extends upwards to the upper part of the pons, where it turns downwards and backwards in the superior cerebellar peduncle to reach the cerebellum.

The spino-cerebellar tracts form, in the main, a homolateral connexion between the spinal cord and the cerebellum. They convey to the cerebellum impulses arising in the locomotor apparatus and essential for the adjustments of muscle tonus and for synergic control during the performance of voluntary movements.

(*c*) The *lateral spinothalamic tract* lies medial to the anterior spino-cerebellar tract in the lateral white column of the spinal cord (fig. 831). Its constituent fibres arise in the head of the posterior grey column of the opposite side (possibly in the substantia gelatinosa) and soon cross the median plane in the white commissure. The tract ascends through the medulla oblongata, where it comes into close relationship with the anterior spinothalamic tract. The two ascend together as the *spinal lemniscus* and reach the ventral portion of the lateral nucleus of the thalamus, where they are relayed to the cerebral cortex.

The lateral spinothalamic tract is an exteroceptive pathway, conveying painful and thermal sensibility, without any discriminative quality so far as painful sensibility is concerned. It is believed that this crude form of sensibility is carried by the non-myelinated or very finely myelinated fibres in the spinal nerves. When they enter the spinal cord they have a tendency to lie

* According to some authorities this tract arises in the superior quadrigeminal body of the same side. See footnote *, p. 899.

on the lateral side of the other fibres of the posterior nerve-root, and they constitute the *posterolateral tract*, the fibres of which soon terminate in the substantia gelatinosa or the adjoining head of the posterior grey column.

Owing to the fact that the fibres which form the lateral spinothalamic tract cross at once, decussating with the corresponding fibres of the opposite side, lesions affecting the commissural area, such as occur in the disease termed syringomyelia, will produce a bilateral loss of painful and thermal sensibilities for the particular areas involved.

(*d*) The *spinotectal tract* is placed medial to the anterior spinocerebellar tract and anterior to the lateral spinothalamic tract. Its constituent fibres arise in the posterior grey column of the opposite side and soon cross the median plane to reach the lateral white column. They ascend to the mid-brain where they terminate in the superior quadrigeminal body (superior colliculus) of the tectum. They provide a pathway for spinovisual reflexes. In this connexion it is to be remembered that the superior quadrigeminal bodies constitute a reflex centre on the visual path and are not concerned with the transmission of visual impulses to the cerebral cortex. Afferent stimuli passing up the spinotectal tract result in movements of the head and eyes towards the source of stimulation.

(*e*) The *posterolateral tract* (fasciculus dorsilateralis) is a small strand situated at the tip of the posterior grey column, close to the entrance of the posterior nerve-roots. It consists of unmyelinated and finely myelinated fibres which do not receive their medullary sheaths until near the close of fœtal life. It is usually regarded as being formed by the lateral group of the fibres of the posterior nerve-roots, which ascend for a short distance in the tract and then enter the substantia gelatinosa, where new fibres arise and pass to the lateral spinothalamic tract. There is ground for supposing that the posterolateral tract is formed by the fibres which convey crude painful and thermal sensibilities in the spinal nerves.

(*f*) The *lateral intersegmental tract* (fasciculus proprius lateralis) constitutes the remainder of the lateral white column, and is continuous in front with the anterior intersegmental tract. It consists chiefly of intersegmental fibres which arise from cells in the grey matter, and, after a longer or shorter course, re-enter the grey matter and ramify in it. Most of the fibres of the anterior and lateral intersegmental tracts are confined to the same side but some cross to the opposite side of the spinal cord. Some of the fibres of the lateral intersegmental tract are continued upwards into the brain under the name of the medial longitudinal bundle. It is believed that this intersegmental pathway may function as an alternative route for exteroceptive sensibility.

Tracts in the posterior white column.—1. Ascending tracts.

This white column comprises two large tracts, viz. the fasciculus gracilis and the fasciculus cuneatus, which are separated from each other by the posterointermediate septum.

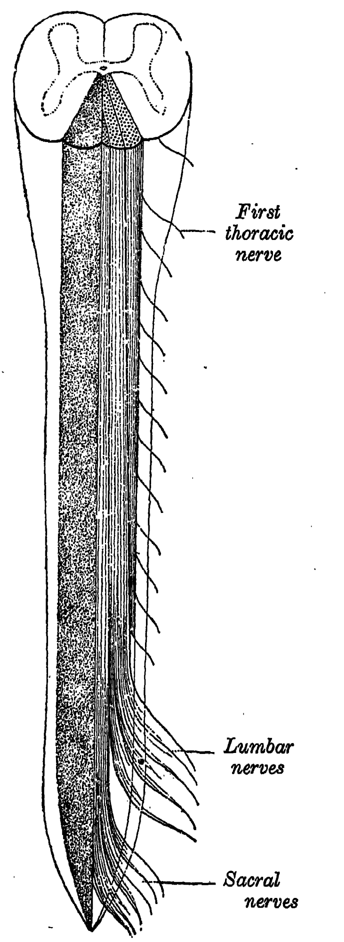
The *fasciculus gracilis* commences at the lowest limit of the spinal cord. Incoming fibres from the medial group of the fibres of the posterior nerve-roots on entering at the posterolateral sulcus divide into short descending and long ascending branches. The latter run upwards in the posterior funiculus, and as the tract ascends it receives accessions from each posterior nerve-root. The fibres which enter in the coccygeal and lower sacral regions are thrust medially by the fibres which enter at a higher level. The fasciculus gracilis, which contains fibres derived from the lower thoracic, lumbar, sacral and coccygeal segments, occupies the medial part of the posterior white column in the upper part of the spinal cord. The *fasciculus cuneatus* commences in the mid-thoracic region and derives its fibres from the posterior roots of the upper thoracic and cervical nerves and, in consequence, is placed on the lateral side of the fasciculus gracilis.

Both fasciculi are heavily myelinated, and the fibres of which they are comprised are larger in the fasciculus cuneatus than they are in the fasciculus gracilis. They ascend uncrossed to the medulla oblongata and terminate there in the nucleus gracilis and cuneatus. Relayed in these nuclei, the majority of the fibres sweep ventrally round the central grey matter (fig. 844), as the *internal arcuate fibres*, and take part in the great sensory decussation. Thereafter, as the *medial lemnisci*, they ascend on each side to the ventral portion of

the lateral nucleus of the thalamus and are there relayed to the cortex of the post-central gyrus. Through the medium of the *external arcuate* fibres (pp. 917 and 919) the remaining fibres of the posterior white column are relayed to the cerebellum.

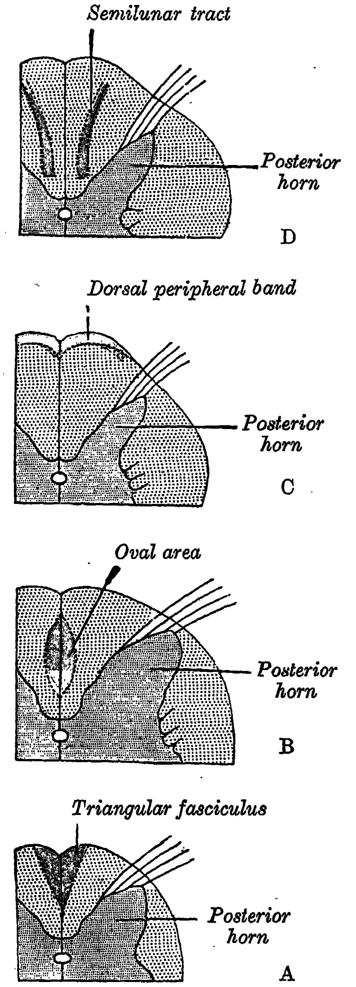
These two tracts, which occupy nearly the whole of the posterior white column, convey all the elements of deep sensibility, with the possible exception

Fig. 833.—A diagram showing the formation of the fasciculus gracilis (Poirier).



The spinal cord viewed from behind. To the left, the fasciculus gracilis is shaded. To the right, the drawing shows that the fasciculus gracilis is formed by the long ascending fibres of the posterior roots and that the sacral nerves lie next the median plane, the lumbar to their lateral side, and the thoracic still more laterally.

Fig. 834.—The descending fibres in the posterior white columns, shown at different levels. (After Testut.)



A. In the conus medullaris. B. In the lumbar region. C. In the lower thoracic region. E. In the upper thoracic region.

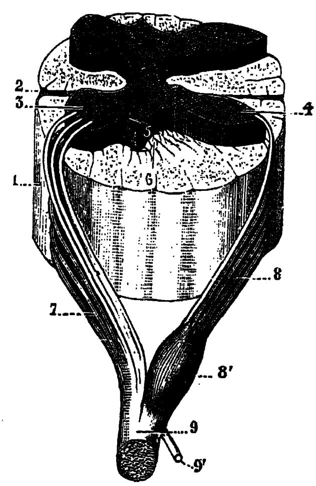
of pressure and pressure pain, and in addition they convey all the afferent fibres which are involved in discriminative sensibility. The higher forms of sensibility, which include tactile discrimination and localisation, all pass up to the medulla oblongata uncrossed in the posterior white columns, together with the fibres which convey sensations of posture and of movements, both active and passive. It is interesting to observe that the exteroceptive pathways of the lateral and anterior white columns are phylogenetically much older than the proprioceptive and discriminative pathway of the posterior white column.

2. **Descending tracts.**—The posterior white column contains some descending fibres which occupy different parts at different levels (figs. 831, 834). In the

cervical and upper thoracic regions they appear as a comma-shaped fasciculus, termed the *semilunar tract*, in the medial part of the fasciculus cuneatus, the blunt end of the fasciculus being directed forwards. In the lower thoracic region they form a *dorsal peripheral strand* on the posterior surface of the spinal cord ; in the lumbar region they are situated by the side of the posterior median septum, and appear on section as a semi-oval bundle ; in the conus medullaris they assume the form of a *triangular strand* in the posteromedial part of the fasciculus gracilis. Collectively these three strands constitute the *septomarginal tract*. These descending fibres in the posterior white column are mainly intersegmental in character and derived from cells in the posterior grey column, but some are said to consist of the descending branches of the medial divisions of the posterior nerve-roots (*vide infra*). The semilunar tract was supposed to belong to the second category, but against this view is the fact that it does not undergo descending degeneration when the posterior nerve-roots are destroyed.

Occupying the anterior or deepest part of the posterior white column is a small strand of fibres named the *posterior intersegmental tract* (fasciculus proprius posterior). It is somewhat crescentic on transverse section, and is placed between the grey commissure and the posterior white column; it is best marked in the lumbar region, but can be traced into the thoracic and cervical regions. Its fibres, which are intersegmental, are derived from the cells of the posterior grey column; they divide into ascending and descending branches which re-enter and ramify in the grey matter.

Fig. 835.—A spinal nerve with its anterior and posterior roots. (Testut.)



1. A portion of the spinal cord viewed from the left side. 2. Anterior median fissure. 3. Anterior grey column. 4. Posterior grey column. 5. Lateral grey column. 6. Formatio reticularis. 7. Anterior root. 8. Posterior root, with 8', its ganglion. 9. Spinal nerve; and 9', its posterior primary ramus.

Roots of the spinal nerves.—Each spinal nerve has two roots, an anterior and a posterior, which are attached to the surface of the spinal cord opposite the corresponding columns of grey matter (fig. 835). Medullation of their fibres precedes medullation of most of the fibres in the spinal cord (p. 898), and commences about the fourteenth week of fœtal life.

The *anterior nerve-root* consists mainly of motor fibres which are the axons of the nerve-cells in the anterior grey column, but in certain regions it contains also the efferent autonomic fibres from the cells in the lateral grey column. A short distance from their origins these axons are invested with medullary sheaths, and, passing forwards, emerge in two or three irregular rows over an area which measures about 3 mm. in width.

The *posterior nerve-root* comprises six or eight fasciculi, attached in linear series along the posterolateral sulcus. It consists of afferent fibres which arise from the nerve-cells in a spinal ganglion. Each ganglion-cell gives off a single fibre which divides in a T-shaped manner into two processes, medial and lateral. The medial processes of the ganglion-cells pass into the spinal cord as the posterior roots of the spinal nerves, while the lateral are directed towards the periphery.

As the posterior nerve-root enters the spinal cord its fibres tend to form medial and lateral bundles, which, however, are not sharply demarcated from each other. The *medial* strand passes directly into the posterior white column ; it consists of coarse fibres, which acquire their medullary sheaths between the fifth and the seventh month of intra-uterine life ; the *lateral* strand is mainly composed of fine fibres, many of which are non-medullated ; they enter the posterolateral tract (p. 901).

After entering the spinal cord, all the fibres of the posterior nerve-roots divide into ascending and descending branches, and these in their turn give

off collaterals which enter the grey matter. The descending branches are short, and soon enter the grey matter. The ascending branches are grouped into long, short and intermediate fibres; the long fibres ascend in the fasciculus cuneatus and fasciculus gracilis as far as the medulla oblongata, where they end by arborising around the cells of the cuneate and gracile nuclei; the short fibres run upwards for a distance of only 5 or 6 mm., and enter the grey matter; while the intermediate fibres, after a somewhat longer course, have a similar destination. All fibres entering the grey matter end by arborising around its nerve-cells; in the thoracic region those of intermediate length are especially associated with the cells of the thoracic nucleus. The collaterals which spring from the ascending and descending branches of the fibres of the posterior nerve-roots end by arborising around the cells in the posterior grey column; in the thoracic region many of these collaterals arborise around the cells of the thoracic nucleus and the cells of the lateral grey column.

THE PARTS OF THE BRAIN DERIVED FROM THE HIND-BRAIN OR RHOMBENCEPHALON

In the development of the spinal cord the reduction of the lumen of the neural tube into a central canal is a striking feature, and is brought about in part by the fusion of the opposed surfaces of the alar laminæ (p. 891). A similar process occurs in the hind-brain in its most caudal part only. Over the greater part of its extent the contained lumen becomes enormously widened, and the narrow roof-plate is expanded in a corresponding manner. The large cavity so formed constitutes the fourth ventricle of the brain.

The caudal portion of the hind-brain becomes the medulla oblongata, while its cephalic portion forms both the pons and the cerebellum. These three structures in the adult occupy the posterior cranial fossa. Below, the medulla oblongata passes through the foramen magnum to become continuous with the spinal cord. Above, the pons is continuous with the mid-brain, which connects it, indirectly, to the cerebrum (fig. 821). The cerebellum lies behind the pons and the medulla oblongata, and it is separated from the occipital lobes of the brain above by a fold of dura mater, named the tentorium cerebelli (p. 1024). It is connected to the brain stem by three pairs of peduncles, termed respectively the inferior, middle and superior cerebellar peduncles. The inferior cerebellar peduncles (restiform bodies) connect the cerebellum to the posterolateral aspects of the medulla oblongata: the middle cerebellar peduncles (brachia pontis) connect it to the corresponding aspects of the pons: the superior cerebellar peduncles (brachia conjunctiva) connect it to the corresponding aspects of the mid-brain.

When the medulla oblongata and the pons, on the one hand, are compared with the spinal cord on the other, it is found that, although they have many features in common, the medulla oblongata and the pons possess many features which are not found in the spinal cord. The enlargement of this part of the brain, therefore, does not indicate an enlargement of the constituent structures of the spinal cord but is to be attributed to the presence of new elements in addition to those which are present in the spinal cord.

The spinal cord shows obvious signs of its segmental origin. The metameric arrangement of its nerve-roots and the structure of its grey matter is sufficient evidence, even although the individual segments are not demarcated on its surface at any stage of its development. The structure of the medulla oblongata and of the pons shows signs of an original metamerism, but this has been profoundly altered by the superposition of a branchiomeric arrangement.

Reference to fig. 210 will show that during the fifth week of development the hind-brain lies in immediate relationship with the dorsal wall of the pharynx and the dorsal extremities of the branchial or visceral arches, and it is not surprising to find that it is from this region of the brain that the arches derive their nerve supply. In this way a branchiomeric arrangement of its constituents is strongly impressed on the medulla oblongata. It must be remembered that

the branchial apparatus in fishes constitutes the respiratory system. Oxygen-bearing water is taken into the mouth and expelled through the gill clefts, and as it flows over the pharyngeal aspects of the branchial arches, it oxygenates the blood which is circulating through them and relieves it of its carbon dioxide. This respiratory function naturally comes under the control of the hind-brain at this stage, and, at a later period in evolution, when the marine habitat was exchanged for a terrestrial one and the branchial apparatus was replaced by the pulmonary apparatus, the control of the new respiratory system remained vested in the same part of the brain. The proximity of the heart to the respiratory apparatus is essential, for the circulatory and respiratory systems must work harmoniously together. On this account the heart and the circulatory system are brought under the control and regulation of the hind-brain, which constitutes the controlling centre for the vital activities of the body.

The transition from a water to an air-breathing apparatus set free the branchial arches and their corresponding clefts and pouches, which were subsequently not allowed to atrophy and disappear in their entirety, but were adapted for new uses. The organs of the lateral line serve to convey to the fish vibrations arising in its vicinity, but these organs were not well adapted to the reception of waves in an air medium. At the headward end of the lateral line, the semicircular canals, the utricle and the saccule had developed to provide the receiving apparatus to enable the animal to maintain its equilibrium, and a further elaboration of this apparatus provided, in the cochlea, the mechanism for the perception of sound waves. New elements were therefore added to the hind-brain in connexion with this new acquisition.

The evolution of the limbs and the increased possibilities of movement which they conferred led to further changes in the structure of the hind-brain. The movements of the fish, though very generalised, are relatively simple, and their co-ordination does not call for any elaborate mechanism. Increased possibility of movement required increased powers of co-ordination in order that the animal might derive the maximum benefit. This demand was met by the growth and elaboration of the vestibular nuclei and the cerebellum, an organ which, as we have already seen, is responsible for synergic control.

To sum up, the hind-brain owes its importance to (1) its control over the heart and the respiratory apparatus ; (2) its control over the alimentary tract and its derivatives ; (3) its association with the modifications of the lateral line and branchial apparatus, which led to the acquisition, first, of the sense of hearing and, subsequently, of the power of phonation, and (4) its synergic control over the musculature of the body.

The Medulla Oblongata

The **medulla oblongata** extends from the lower margin of the pons to a transverse plane passing above the first pair of cervical nerves ; this plane corresponds with the upper border of the atlas behind, and the middle of the odontoid process of the axis in front ; at this level the medulla oblongata is continuous with the spinal cord. The anterior surface of the medulla oblongata is separated from the basilar part of the occipital bone and the upper part of the odontoid process by the membranes of the brain, and the occipito-axial ligaments. Posteriorly it is received into the fossa between the hemispheres of the cerebellum, and the upper portion of this surface forms the lower part of the floor of the fourth ventricle. The vertebral arteries pass upwards and forwards in relation to its lateral surfaces ; they then curve forwards to its anterior surface and unite at the lower border of the pons to form the basilar artery.

The medulla oblongata is somewhat piriform in shape (fig. 836), its broad extremity being directed upwards towards the pons, while its narrow lower end is continuous with the spinal cord. It measures about 3 cm. longitudinally, 2 cm. transversely at its widest part, and 1·25 cm. anteroposteriorly. The central canal of the spinal cord is prolonged into its lower half, and then opens into the cavity of the fourth ventricle ; the medulla oblongata may therefore be divided into a lower part containing the central canal, and an upper part corresponding with the lower portion of the fourth ventricle. Its anterior and posterior surfaces are marked by median fissures.

The **anterior median fissure** contains a short fold of pia mater, and extends along the entire length of the medulla oblongata; below, it is continuous with the anterior median fissure of the spinal cord; above, it ends at the lower border of the pons in a small triangular expansion termed the *foramen cæcum.* Its lower part is interrupted by bundles of fibres which cross obliquely from one side to the other, and constitute the *decussation of the pyramids.* Some fibres, termed the *external arcuate fibres,* emerge from the fissure above this decussation and curve laterally over the surface of the medulla oblongata.

FIG. 836.—The medulla oblongata, pons and mid-brain. Viewed from below.

The wall of the lateral recess of the fourth ventricle is shown in *blue,* and the choroid plexus which protrudes through the foramen of the lateral recess into the subarachnoid space is coloured *crimson.*

Note that the lateral recess covers the medial part of the flocculus and is itself partially obscured by the glossopharyngeal nerve.

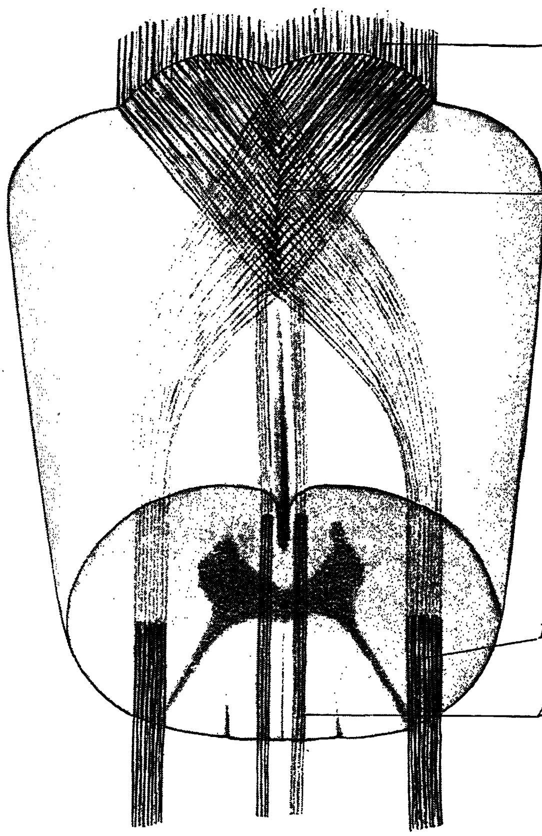
The **posterior median fissure** is a narrow groove which exists only in the closed part of the medulla oblongata; it is continuous below with the posterior median sulcus of the spinal cord, but becomes rapidly shallower from below upwards, and ends about the middle of the medulla oblongata, where the central canal expands into the cavity of the fourth ventricle.

The two fissures divide the lower part of the medulla oblongata into lateral halves which, on surface view, appear to be continuous with the halves of the spinal cord. In the upper part the halves are separated by the anterior median fissure, and by a median *raphe* which extends from the bottom of the fissure to the median sulcus of the floor of the fourth ventricle. Further, certain of the cranial nerves pass through the substance of the medulla oblongata, and are attached to its surface in series with the roots of the spinal nerves; thus, the fibres of the hypoglossal nerve correspond in position with the anterior roots of the spinal nerves, and emerge in linear series from a furrow termed the *anterolateral sulcus.* Similarly, the accessory, vagus, and glossopharyngeal

nerves are in line with the posterior roots of the spinal nerves (p. 1079), and are attached to the bottom of a sulcus named the *posterolateral sulcus*. Advantage is taken of this arrangement to subdivide each half of the medulla oblongata into anterior, middle and posterior regions. Although these three regions appear to be directly continuous with the corresponding white columns of the spinal cord, they do not contain precisely the same nerve-fibres, since some of the fasciculi of the spinal cord end in the medulla oblongata, while others alter their course in passing through it.

The **anterior region** of the medulla oblongata (fig. 836) is named the *pyramid*, and lies between the anterior median fissure and the anterolateral sulcus.

FIG. 837.—A scheme showing the decussation of the pyramids.



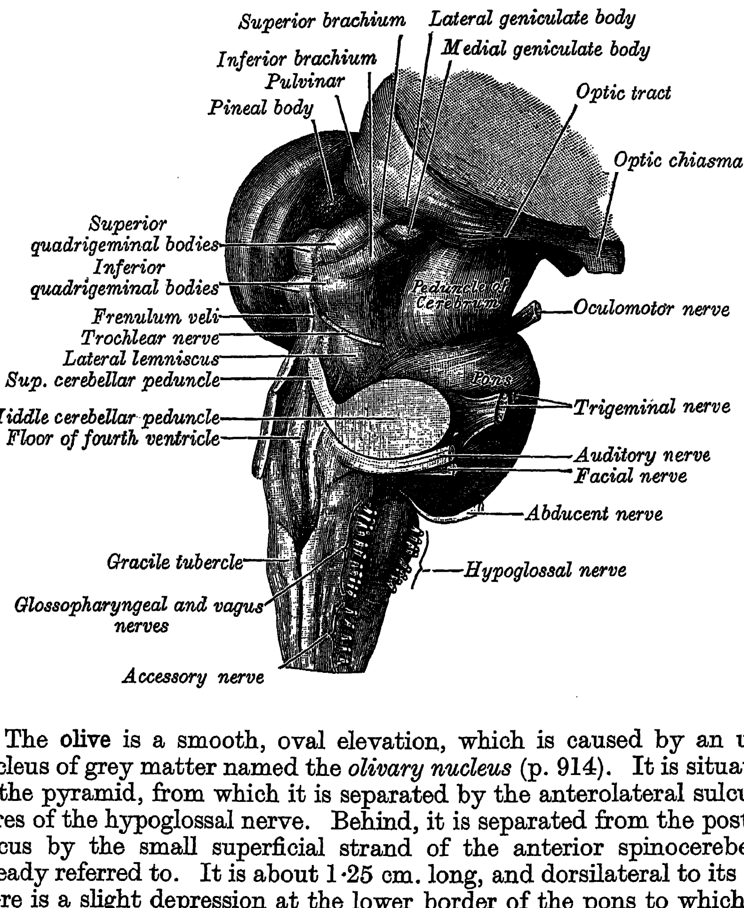
Its upper end is slightly constricted and between it and the pons the fibres of the abducent nerve emerge; below, it tapers into the anterior white column of the spinal cord, with which it appears to be directly continuous.

The two pyramids contain the motor fibres which pass from the brain to the spinal cord. When traced downwards, two-thirds or more of these fibres leave the pyramids in successive bundles, and decussate in the anterior median fissure, forming what is termed the *decussation of the pyramids*. Having crossed the median plane, they pass down in the posterior part of the lateral white column of the spinal cord as the lateral cerebrospinal tract. The remaining fibres—i.e. those in the lateral part of the pyramid—do not cross the median plane, but descend as the anterior cerebrospinal tract (fig. 837) into the anterior white column of the same side of the spinal cord.

The **lateral region** of the medulla oblongata (fig. 838) is limited in front by the anterolateral sulcus and the roots of the hypoglossal nerve, and behind by the posterolateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves. Its upper part consists of a prominent oval mass which is

named the *olive*, while its lower part is of the same width as the lateral column of the spinal cord, and appears on the surface to be a direct continuation of it. As a matter of fact, only a portion of the lateral column of the spinal cord is continued upwards into this region, for the lateral cerebrospinal tract is derived from the pyramid of the opposite side, and most of the fibres of the posterior spinocerebellar tract leave it to enter the inferior cerebellar peduncle in the posterior region. The lateral intersegmental tract and the anterior spinocerebellar tract are continued upwards into the lateral region of the medulla oblongata. Most of these fibres dip beneath the olive and disappear from the surface; but a small strand remains superficial, and ascends between the olive and the posterolateral sulcus.

Fig. 838.—The hind-brain and the mid-brain. Posterolateral aspect.



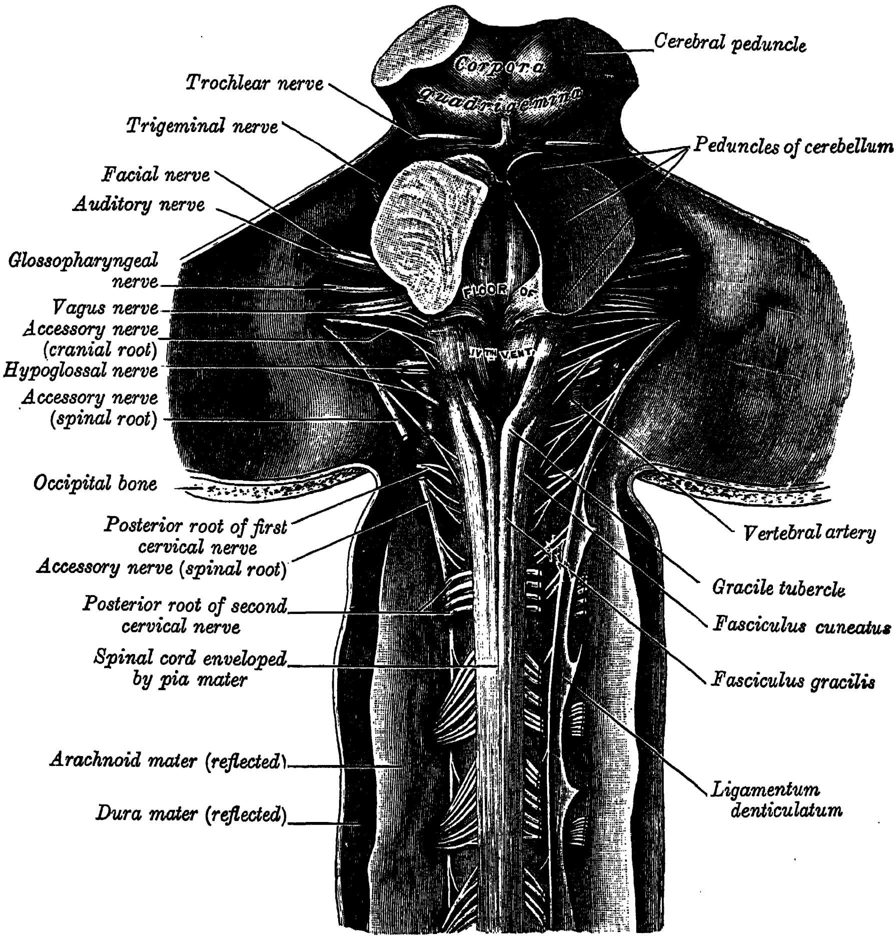
The **olive** is a smooth, oval elevation, which is caused by an underlying nucleus of grey matter named the *olivary nucleus* (p. 914). It is situated lateral to the pyramid, from which it is separated by the anterolateral sulcus and the fibres of the hypoglossal nerve. Behind, it is separated from the posterolateral sulcus by the small superficial strand of the anterior spinocerebellar tract already referred to. It is about 1·25 cm. long, and dorsilateral to its upper end there is a slight depression at the lower border of the pons to which the roots of the facial nerve are attached. The external arcuate fibres emerge from the anterior median fissure, and wind backwards across the pyramid and the olive and enter the inferior cerebellar peduncle.

The **posterior region** of the medulla oblongata (fig. 839) lies behind the posterolateral sulcus and the roots of the accessory, vagus and glossopharyngeal nerves, and, like the lateral region, is divisible into a lower and an upper portion.

The *lower part* is limited behind by the posterior median fissure, and consists of the *fasciculus gracilis* and the *fasciculus cuneatus* of the spinal cord. The fasciculus gracilis is placed along the side of the posterior median fissure, and is separated from the fasciculus cuneatus by a faint longitudinal groove and a septum. These two fasciculi are at first vertical; but at the lower part of the fourth ventricle they diverge from the median plane, and each presents an elongated swelling. The swelling on the fasciculus gracilis is named the *gracile*

tubercle, and is produced by the upper end of a subjacent nucleus of grey matter termed the *nucleus gracilis*; that on the fasciculus cuneatus is termed the *cuneate tubercle*, and is caused similarly by a grey nucleus named the *nucleus cuneatus*. The fibres of these two fasciculi end by arborising around the cells in their respective nuclei. A third elevation may be present in the lower part of the posterior region of the medulla oblongata. It lies between the fasciculus cuneatus and the roots of the accessory nerve, and is narrow below but wider above. It is produced by a nucleus which is continuous below with the substantia gelatinosa, and in which the fibres of the spinal tract of the trigeminal

FIG. 839.—The upper part of the spinal cord and the hind- and mid-brains. Exposed from behind.



nerve end; these fibres separate the nucleus from the surface of the medulla oblongata. The *obex* and the *tæniæ of the fourth ventricle* are described on p. 939.

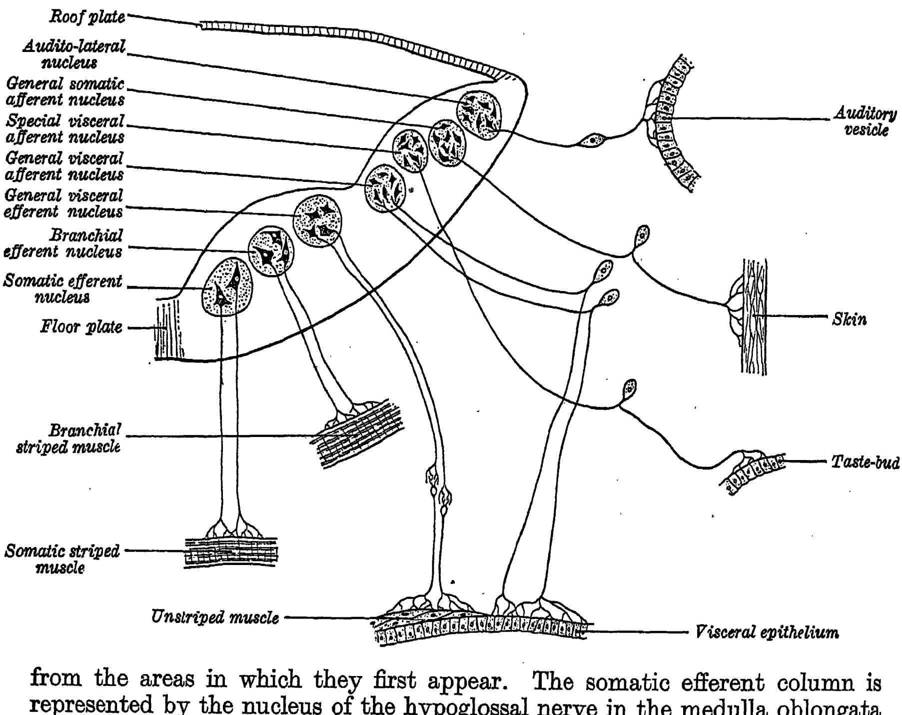
The *upper part* of the posterior region of the medulla oblongata is occupied by the *inferior cerebellar peduncle*, a thick rope-like strand situated between the lower part of the fourth ventricle and the roots of the glossopharyngeal and vagus nerves. The two inferior cerebellar peduncles leave the dorsilateral aspect of the medulla oblongata and pass to the cerebellum. As they ascend, they diverge from each other, and assist in forming the lower parts of the lateral boundaries of the fourth ventricle; higher up, they are directed backwards, each passing to the corresponding cerebellar hemisphere. Near their entrance into the cerebellum they are crossed by several strands of fibres which run to the median sulcus of the floor, or anterior wall, of the fourth ventricle and are named the *auditory striæ* (striæ medullares). The inferior

cerebellar peduncle is not, although it appears to be, the upward continuation of the fasciculus gracilis and fasciculus cuneatus, since the fibres of these fasciculi end in the nucleus gracilis and nucleus cuneatus; its constitution is described on p. 919.

The stages in the development of the hind-brain have been described in detail in a preceding section (p. 111), but certain points in the process require special emphasis in order that the internal structure of the medulla oblongata and the pons may be appreciated adequately.

Attention has been drawn to the expansion of the roof-plate which accompanies the formation of the pontine flexure, and to the consequent alteration in the position of the alar and basal laminæ (fig. 840). In their subsequent growth these laminæ do not form continuous columns of grey matter throughout the hind-brain, as they do in the spinal cord. Instead they become broken up into nuclear masses of varying size and extent, and many of them migrate

Fig. 840.—Diagram of a transverse section through the developing hind-brain to show the relative positions of the nuclei of the different varieties of nerve components.



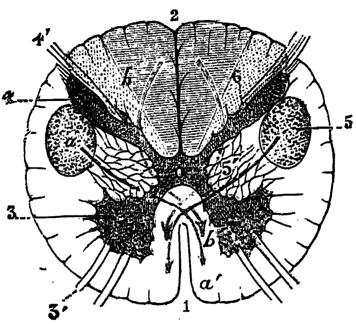
from the areas in which they first appear. The somatic efferent column is represented by the nucleus of the hypoglossal nerve in the medulla oblongata and by the nucleus of the abducent nerve in the pons; but these two nuclei are separated from each other by an interval in which the column is unrepresented. The branchial (special visceral) efferent column, which is found only in the upper segments of the spinal cord, is represented by the nucleus ambiguus in the medulla oblongata and by the motor nuclei of the facial and the trigeminal nerves in the pons. The nucleus ambiguus gives origin to those fibres of the glossopharyngeal and vagus nerves which are distributed to striped muscle, and to some of the fibres of the accessory nerve. These nerves are intimately associated with the visceral arches. The mandibular division of the trigeminal supplies the first, the facial the second, the glossopharyngeal the third and the vagus and accessory the remaining arches. The splanchnic efferent column is represented by the dorsal nucleus of the vagus in the medulla oblongata and by the superior and inferior salivary nuclei.

In the same way, the derivatives of the alar laminæ constitute a number of separated masses of grey matter. The general visceral afferent column is represented by a portion of the dorsal nucleus of the vagus; the general somatic afferent column by the nuclei of termination of the trigeminal nerve; the

special visceral afferent column by the nucleus of the tractus solitarius, which receives gustatory fibres from the facial, the glossopharyngeal and the vagus nerves ; and the special somatic afferent column by the nuclei of the cochlear divisions of the auditory nerve (fig. 840). As already described (p. 901), the proprioceptive fibres ascend uncrossed, and without being relayed, through the spinal cord. There are, however, in the medulla oblongata and the pons, nuclei which are concerned with this variety of sensibility. The nuclei of termination of the vestibular division of the auditory nerve, the olivary nuclei, and many other smaller nuclei represent this column.

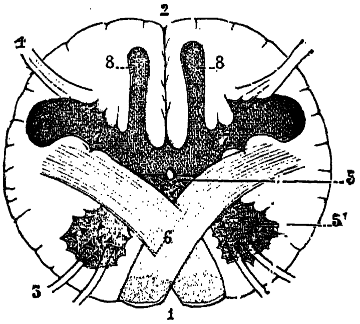
Owing to the growth of the cerebrum, which sends down large fibre tracts through the hind-brain, and the growth of the spinal cord, which sends similar fibre tracts upwards to the cerebrum, the relative positions of the various constituents of these columns may undergo considerable alteration. In addition, it has been clearly demonstrated that during the course of development, nerve-cells or groups of nerve-cells are capable of active migration. Ariëns Kappers has pointed out that a nerve-cell tends to remain as near as possible to its source of stimulation, and that when, owing to the development

Fig. 841.—A section through the medulla oblongata below the level of the decussation of the pyramids. Schematic. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3. Anterior horn (in red), with 3', anterior root. 4. Posterior horn (in blue), with 4', posterior root. 5. Lateral cerebrospinal tract. 6. Posterior white column. The arrow, $a\ a'$, indicates the course of the decussation of the pyramids ; the arrow, $b\ b'$, that of the sensory decussation.

Fig. 842.—A section through the medulla oblongata at the level of the decussation of the pyramids. Schematic. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3. Motor roots. 4. Sensory roots. 5. Base of the anterior horn, from which the head (5') has been detached by the lateral cerebrospinal tract. 6. Decussation of the pyramids. 7. Posterior horn (in blue). 8. Nucleus gracilis.

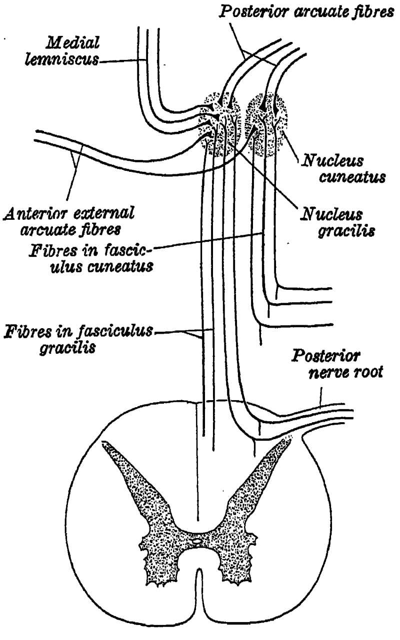
of neighbouring structures, the danger of separation arises, it will bodily migrate in the direction from which its stimuli come. The nature of the attraction exerted by the source of stimulation is unknown, and Kappers has given the phenomenon the name of Neurobiotaxis. Cells can migrate in this way only by a lengthening of their axons, which therefore map out the route taken by the cell or group of cells in its transit. The curious course of the fibres arising from the facial nucleus and the nucleus ambiguus illustrate this point clearly (p. 924).

The internal structure of the medulla oblongata.—(1) *A transverse section through the lower part of the medulla oblongata* shows many of the appearances of a transverse section through the upper end of the spinal cord. The posterior, lateral and anterior white columns can be identified easily, and they contain the same nerve tracts. The grey matter shows two very striking alterations. The anterior horn is separated from the grey matter surrounding the central canal by the pyramidal fibres, which are coursing backwards and laterally to reach the lateral white column. In the upper part of the medulla oblongata the pyramidal fibres occupy its ventrimedial portion, but in the lower part the majority of them run backwards and laterally, crossing the median plane and decussating in front of the central grey matter. The decussation of the great motor tracts [*decussation of the pyramids*] constitutes the most striking feature in sections of the medulla oblongata at this level. The actual proportion of the fibres which take part is subject to variation, but, as a rule, 75 per cent.

of them do so and continue down the spinal cord in the lateral white column as the lateral, or crossed, cerebrospinal (pyramidal) tract. The remaining fibres retain their ventrimedial position and descend in the anterior white column of the spinal cord as the anterior, or direct, cerebrospinal tract. As a result of this decussation the anterior intersegmental tract of the spinal cord is thrust backwards towards the central grey matter, which also takes up a more dorsal position so that the central canal inclines backwards as it ascends. The continuity between the anterior grey column and the central grey matter, maintained throughout the whole length of the spinal cord, is severed. At higher levels the detached anterior column rapidly diminishes in size and merges into the grey matter of the formatio reticularis (p. 914), but at this level it contains the upper end of the nucleus which gives origin to the spinal part of the accessory nerve.

The outline of the posterior horn of the grey matter can still be made out, but it, too, has undergone some modification. A narrow, strip-like portion of grey matter appears in the heart of the fasciculus gracilis, continuous ventrally with the base of the posterior horn. This constitutes the lower end of the *nucleus gracilis*, which extends upwards as far as the lower limit of the fourth ventricle and forms an elevation on the posterior surface of the medulla oblongata already described as the gracile tubercle on p. 908. A second projection from the base of the posterior horn invades the ventral part of the fasciculus cuneatus, and constitutes the *nucleus cuneatus*.

FIG. 843.—A scheme showing the connexions of the fasciculus gracilis and the fasciculus cuneatus.



The *substantia gelatinosa* is a prominent feature, capping the apex of the posterior horn of the grey matter. In this situation it constitutes the *nucleus of the spinal tract of the trigeminal nerve*, and the fibres of the tract itself are interposed between the nucleus and the surface of the medulla oblongata. It will be considered in detail in a subsequent section (p. 924).

(2) *A transverse section made through the upper part of, or just above, the decussation of the pyramids* shows an accentuation of the differences already noted and the appearance of certain new elements.

The nucleus gracilis has increased in breadth and the fibres of its corresponding fasciculus are grouped together on its dorsal, medial and lateral surfaces ; and the nucleus cuneatus has undergone a similar change. Both still retain their continuity with the central grey matter. The fibres of the fasciculus gracilis and cuneatus have ascended uncrossed through the spinal cord, and they terminate in their respective nuclei at different levels by arborising with the dendrites of their contained nerve-cells. New fibres arise in the nuclei and constitute the second neurone on the pathway of discriminative and proprioceptive sensibilities. These *internal arcuate fibres* emerge from the ventral aspects of the nuclei and, curving forwards and laterally at first round the central grey matter, they bend medially to reach the median plane, where they decussate with the corresponding fibres of the opposite side (fig. 844). Thereafter, they turn upwards and ascend close to the median raphe, constituting the *medial lemniscus*. This great *sensory decussation* occurs in the area dorsal to the pyramids and in front of the central grey matter, which is in this way thrust still further backwards towards the dorsal surface of the medulla oblongata. As the internal arcuate fibres sweep forwards they interrupt the

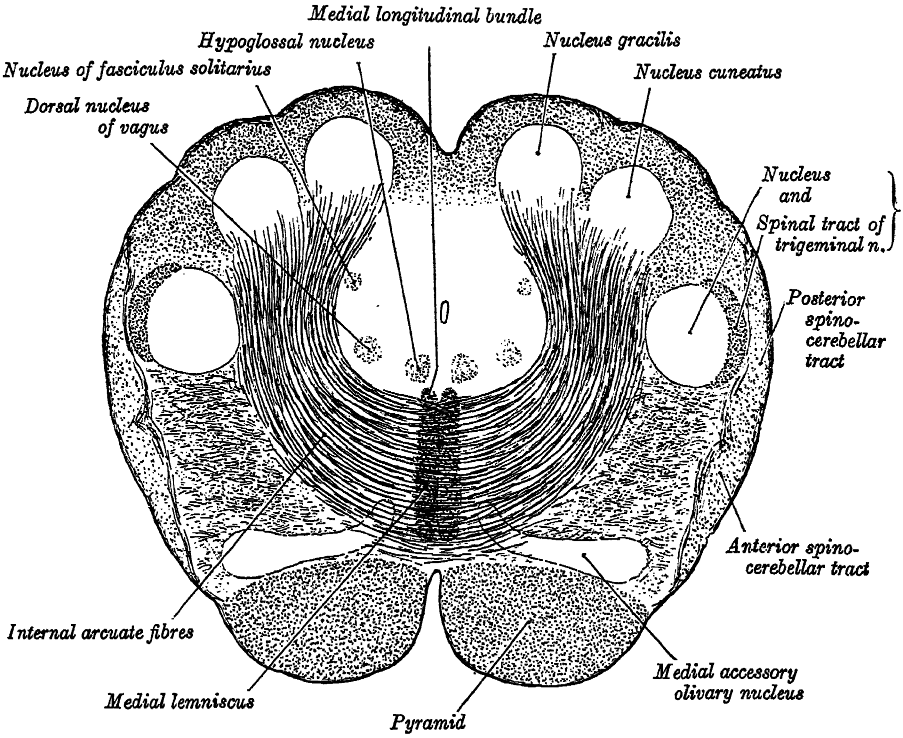
grey matter which connects the substantia gelatinosa with the central grey matter.

In addition, the nucleus gracilis and the nucleus cuneatus give origin to the *anterior* and *posterior external arcuate fibres* (pp. 917 and 919).

The *nucleus of the spinal tract of the trigeminal nerve* is now severed from the central grey matter by the internal arcuate fibres, and it is separated from the lateral surface of the medulla oblongata only by the fibres whose terminal nucleus it constitutes.

Two additional collections of grey matter are found at this level. One lies dorsal to the lateral part of the pyramid, while the other is placed to its medial side and not far from the median plane. These are portions of the *medial accessory olivary nucleus* and will be considered together with the olivary nucleus.

FIG. 844.—A transverse section through the sensory decussation. (Semidiagrammatic. After Villiger.)



The central grey matter, now occupying a position near the dorsal surface of the medulla oblongata, contains three important nuclei. A prominent group of large motor nerve-cells is situated ventrimedially, in the position of the somatic efferent column. This is the *nucleus of the hypoglossal nerve*. It extends upwards into the open part of the medulla oblongata where it lies under the medial part of the trigonum hypoglossi in the floor of the fourth ventricle. Dorsilateral to the hypoglossal nucleus, in the position of the splanchnic efferent column, there is a second group of cells, which constitutes the *dorsal nucleus of the vagus*. It contains cells of two different types. The larger cells give rise to the fine fibres which innervate unstriped muscle, while the smaller spindle-shaped cells probably represent the splanchnic afferent column (fig. 840). The dorsal nucleus of the vagus, at a higher level, lies to the lateral side of the hypoglossal nucleus in the floor of the fourth ventricle and corresponds in position to the trigonum vagi.

A third group of cells lies dorsilateral to the dorsal nucleus of the vagus, at this level. It is the *nucleus of the tractus solitarius*, and it is intimately related to a group of descending fibres which constitute the *tractus solitarius* itself. As

the nucleus is traced upwards it comes to lie a little more deeply in the substance of the medulla oblongata, on the ventrilateral aspect of the dorsal nucleus, with which it is practically coextensive. The tractus solitarius contains afferent fibres from the facial, glossopharyngeal and vagus nerves, which enter the nucleus in that order from above downwards, conveying to it gustatory sensibility from the mucous membrane of the tongue.

In addition, numerous scattered islets of grey matter are found in the centre of the ventrilateral portion of the medulla oblongata. They occupy an area which is freely intersected by nerve fibres running in all directions and which is therefore termed the *formatio reticularis*.

The white matter has undergone an important rearrangement. The *pyramidal tracts* constitute two large bundles placed on the ventral part of the section, one on each side of the anterior median fissure. Dorsally they are related to the accessory olivary nuclei and the sensory decussation.

The fibres of the *medial lemniscus*, after emerging from the sensory decussation, turn upwards abruptly and form a flattened tract, closely applied to the median raphe. In this position they ascend to the pons, increasing in bulk as additional fibres join them from the upper levels of the decussation. Ventrally they are related to the medial part of the pyramidal tract, and dorsally they are separated from the nucleus of the hypoglossal nerve by the medial longitudinal bundle and the tectospinal tract. On its lateral side lies the grey matter of the formatio reticularis intersected by the internal arcuate fibres. In the upper part of the medulla oblongata and as it enters the pons the tract undergoes an alteration in position and it comes to lie in a coronal plane in the ventral part of the tegmental region (fig. 850). In the mid-brain it occupies a similar position, dorsal to the substantia nigra, but it gradually inclines laterally. In this situation some of its fibres terminate in the substantia nigra and others in the superior quadrigeminal bodies. The majority of the fibres ascend on the lateral aspect of the red nucleus and enter the ventrilateral surface of the thalamus, where the fibres of the second neurone in the pathway of discriminative and proprioceptive sensibilities terminate by arborising round the dendrites of the cells of the ventral portion of the lateral thalamic nucleus. There the fibres of the third neurone begin, and they pass upwards to the cortex of the postcentral gyrus.

The *medial longitudinal bundle* forms a small compact tract of nerve-fibres, situated close to the median plane and ventral to the hypoglossal nucleus. Below, it is continuous with the anterior intersegmental tract of the spinal cord, but it has been thrust dorsally by the pyramidal and the sensory decussations. It is continued upwards through the pons and the mid-brain in the same position relative to the central grey matter and the median plane, and therefore comes into intimate relationship throughout its course with the somatic efferent column of the grey matter. The constituent fibres of the tract run relatively short courses within it, for they are derived from a variety of sources, which are detailed on p. 949. The tract affords a pathway for communications passing between the nuclei of the cranial nerves.

The spinocerebellar, spinothalamic, spinotectal, olivospinal, vestibulospinal and rubrospinal tracts are all found in the anterolateral area, limited dorsally by the nucleus of the spinal tract of the trigeminal nerve and ventrally by the pyramid.

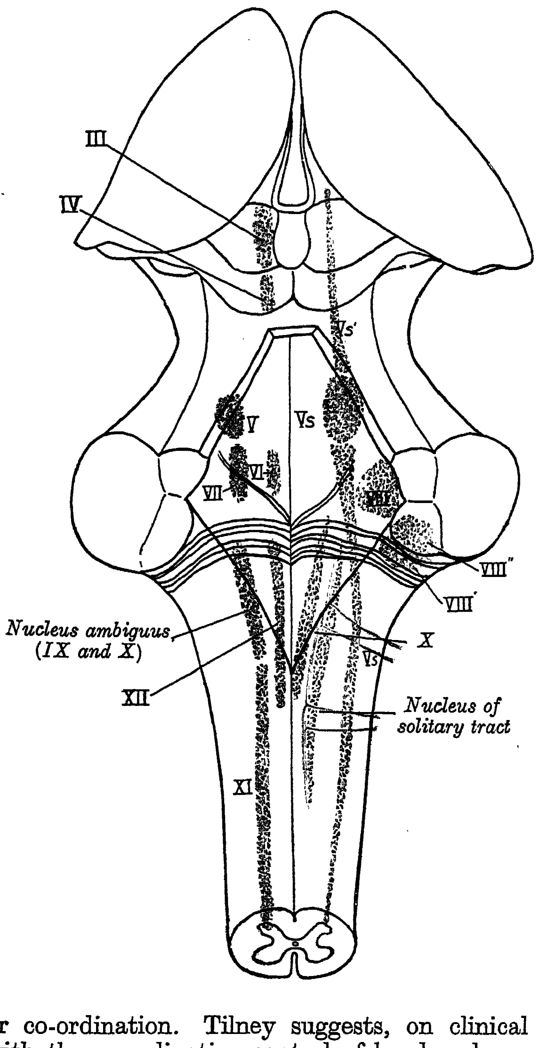
(3) *A transverse section through the medulla oblongata made on a level with the inferior limit of the fourth ventricle*, shows the appearance of a number of new elements, together with most of those already described at a lower level.

The grey matter shows a distinct increase in amount owing to the presence of the large olivary nucleus, the nucleus arcuatus and nuclei associated with the glossopharyngeal, vagus and accessory nerves.

The **olivary nucleus** (inferior olivary nucleus) is a large hollow mass of grey matter, with irregularly crenated walls and a longitudinal hilum, which is situated on its medial side. Situated dorsal to the pyramid, the nucleus underlies the surface elevation of the olive and extends upwards almost to the pons. Derived from the rhombic lip of the alar lamina (p. 112), its cells migrate ventrally and medially into the basal lamina. The site of origin of its cells indicates a probable connexion with the vestibular apparatus and the cerebellum, and that such a connexion does exist is demonstrated by the large

number of fibres which arise from the small cells of the nucleus and constitute the *olivocerebellar tract.* These fibres emerge from the hilum or through its medial wall, and run medially, intersecting the fibres of the medial lemniscus. They cross the median plane, and, sweeping dorsally, traverse the olivary nucleus of the opposite side, intersect the spinothalamic and rubropsinal tracts and nucleus of the spinal tract of the trigeminal nerve and enter the inferior cerebellar peduncle by which they are conveyed to the cerebellum. Despite the size of the nucleus and the ease with which its cerebellar connexions can be demonstrated, it has hitherto been found impossible to determine with certainty the afferent paths which lead to it. Several such pathways have, however, been described by Helweg, Flechsig, Bechterew and others. It appears probable that fibres reach the nucleus from the spinal cord, but whether they ascend in a separate spino-olivary tract or whether they are derived from the medial lemniscus and spinothalamic tracts, as Ramon y Cajal has suggested, is not clear. A group of fibres can be traced downwards through the mid-brain and pons, many of which are believed to end in the lateral aspect of the olivary nucleus, but, although they have been termed the thalamo-olivary fasciculus, their source of origin has not been demonstrated satisfactorily; some authorities ascribe them to the red nucleus and the globus pallidus of the lentiform nucleus. This bundle of fibres is sometimes described as the *central tegmental fasciculus,** and many of its constituents are continued downwards into the anterior intersegmental tract of the spinal cord.

FIG. 845.—The nuclei of the cranial nerves schematically represented. Dorsal aspect. Motor nuclei in *red*; sensory in *blue*. (The olfactory and optic centres are not shown.)



On account of its intimate and free communication with the cerebellum it is clear that the olivary nucleus plays some intermediate part in muscular co-ordination. Tilney suggests, on clinical grounds, that it is associated with the co-ordinative control of head and eye movements.

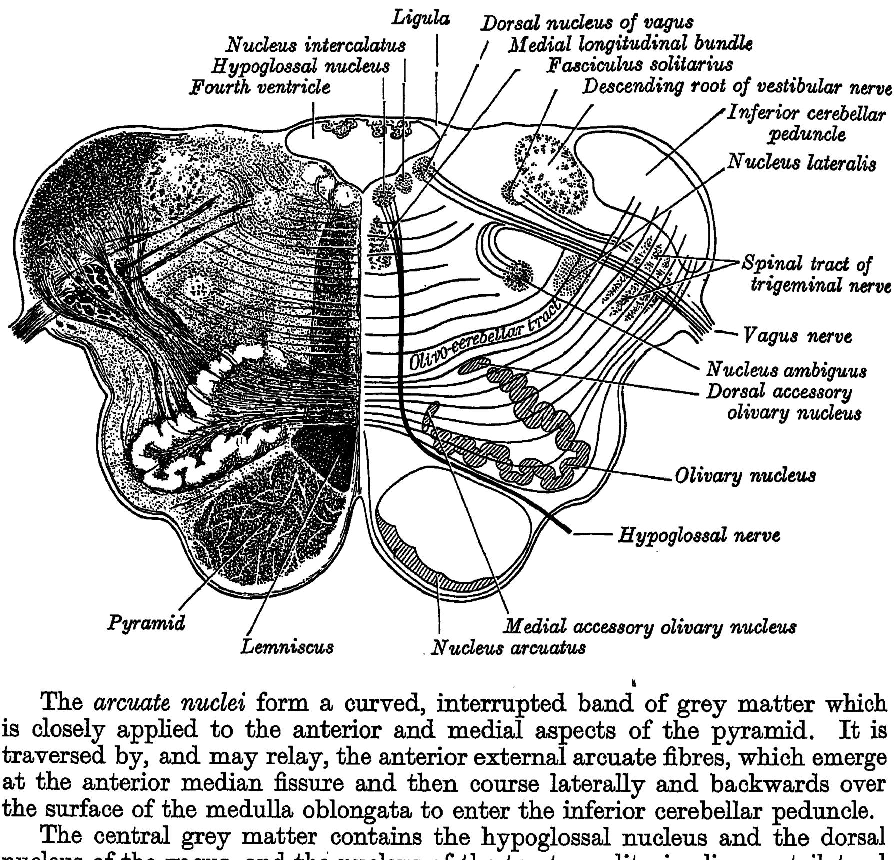
The *medial accessory olivary nucleus* is a curved lamina of grey matter which is found at this level. The concavity of the curve is directed laterally and the nucleus is interposed between the medial lemniscus and the pyramid, on the one hand, and the medial and ventral aspects of the olivary nucleus on the other.

The *dorsal accessory olivary nucleus* is a second lamina of grey matter, placed dorsal to the medial part of the olivary nucleus.

* For a detailed account, see *Modern Problems in Neurology,* by S. A. K. Wilson. Wood & Co., New York, 1929.

Both the olivary and the accessory nuclei are intimately associated with the cerebellum. Phylogenetically, the accessory nuclei are older than the olivary nucleus, and they send their fibres to the palæocerebellum (p. 928). The olivary nucleus is a later acquisition and, in the course of evolution, it has enlarged in a tailward direction. The destination of its fibres in the human brain is in harmony with its phylogenetic history, for those which arise from its upper end and the lips of the upper part of the hilum pass to the palæocerebellum, whereas those from the larger, caudal portion proceed to neocerebellum (p. 929). Gordon Holmes and Stewart have been able to demonstrate that different parts of the olivary nucleus are each represented in a definite part of the cerebellar cortex. The interdependence of the two has been emphasised recently by Brouwer, who has shown that neocerebellar atrophy is associated with a corresponding atrophy of all but the upper and medial part of the olivary nucleus.

FIG. 846.—A transverse section through the medulla oblongata below the middle of the olive.



The *arcuate nuclei* form a curved, interrupted band of grey matter which is closely applied to the anterior and medial aspects of the pyramid. It is traversed by, and may relay, the anterior external arcuate fibres, which emerge at the anterior median fissure and then course laterally and backwards over the surface of the medulla oblongata to enter the inferior cerebellar peduncle.

The central grey matter contains the hypoglossal nucleus and the dorsal nucleus of the vagus, and the nucleus of the tractus solitarius lies ventrilateral to the last-named.

A small isolated group of large motor nerve-cells, termed the *nucleus ambiguus*, is placed deeply in the formatio reticularis. It extends upwards as far as the upper limit of the dorsal nucleus of the vagus. The fibres which emerge from its upper end join the glossopharyngeal nerve, and those which emerge at a lower level join the fila of the vagus nerve. Inferiorly it is continuous with a nucleus which gives origin to fibres of the cranial root of the accessory nerve. This nucleus represents the branchial (special visceral) efferent column in the medulla oblongata, and the fibres which arise from its cells are all distributed to striped muscle of branchial origin (p. 100). The manner in which these fibres behave on leaving the nucleus indicate that it has migrated from its normal position in relation to the central grey matter,

presumably under the influence of neurobiotaxis, for they pass dorsally and medially for a short distance before they curve laterally to join the emerging fila of the vagus and glossopharyngeal nerves (fig. 846).

The nucleus gracilis and the nucleus cuneatus, now diminishing in size and irregular in outline, occupy the dorsilateral portion of the section, and ventral to them the nucleus of the spinal tract of the trigeminal nerve, which is here intersected by the fibres of the olivocerebellar tract and the emerging fila of the vagus, can be recognised without difficulty.

The white matter of the medulla oblongata shows little change at this level. The pyramid, the medial lemniscus, the tectospinal tract and the medial longitudinal bundle occupy the same relative positions as they did at a lower level. The fibres of the olivocerebellar tract, sweeping across the median plane and turning dorsally to join the inferior cerebellar peduncle, have already been described in connexion with the olivary nucleus (p. 915). The *anterior external arcuate fibres*, which arise from the nucleus gracilis and cuneatus of the opposite side, emerge from the anterior median fissure and course over the surface of the medulla oblongata. They pass through the nucleus arcuatus and may be relayed there. Then they run obliquely backwards and upwards over the surface of the olive and the spinal tract of the trigeminal nerve, where they come into relationship with the posterior spinocerebellar tract, with which they ascend to enter the inferior cerebellar peduncle.

The emerging fila of the hypoglossal nerve leave the ventral aspect of its nucleus and run forwards through the formatio reticularis. Passing lateral to the medial lemniscus and medial to the olivary nucleus, they curve laterally to emerge from the anterolateral sulcus. A relatively small lesion in the ventral part of the medulla oblongata at this level will therefore involve both the pyramidal tract and the hypoglossal nerve, causing a peculiar crossed paralysis. The muscles of the tongue are paralysed on the same side as the lesion, but it is the limbs of the opposite side of the body that are affected, for the lesion is situated above the level of the pyramidal decussation.

More dorsally, the formatio reticularis is traversed by the fila of the vagus, travelling between the posterolateral sulcus and the dorsal nucleus, the nucleus ambiguus and the nucleus of the tractus solitarius.

It should be observed that the *spinal lemniscus*, which is formed about this level by the union of the anterior and lateral spinothalamic tracts, is closely related to the nucleus ambiguus as it ascends through the upper part of the medulla oblongata. A small lesion in the ventral part of the formatio reticularis may cause paralysis of the vocal fold and of the soft palate of the same side, but a loss of sensibility to pain and temperature on the opposite side of the body.

(4) *A transverse section through the uppermost part of the medulla oblongata* shows less striking changes. The *olivary nucleus* occupies the same relative position, but the accessory olivary nuclei are being broken up and tend to disappear.

Additional elements are present in the central grey matter. The *medial nucleus of the vestibular nerve* lies on the lateral side of the dorsal vagal nucleus, under the vestibular area of the floor of the fourth ventricle. It is the largest of the four nuclear masses in which the fibres of the vestibular nerve terminate, and it extends upwards into the pons, separated from the floor of the fourth ventricle by the auditory striæ. In this nucleus fibres from the vestibular nerve are relayed to the cerebellum and to the medial longitudinal bundle.

The *inferior nucleus of the vestibular nerve* lies on the lateral side of the medial nucleus, intervening between it and the inferior cerebellar peduncle. It extends to a lower level than the medial nucleus, but it does not extend so high into the pons. It receives the descending branches of the incoming fibres of the vestibular nerve.

The dorsal nucleus of the vagus is separated from the upper end of the hypoglossal nucleus by a collection of cells which is termed the *nucleus intercalatus*. This small nucleus occupies the lateral part of the trigonum hypoglossi. A second small nucleus lies ventral to the hypoglossal nucleus and dorsilateral to the medial longitudinal bundle. It is believed to function as a respiratory centre.

Fig. 847.—The nuclei of origin of the cranial motor nerves schematically represented. Lateral aspect.

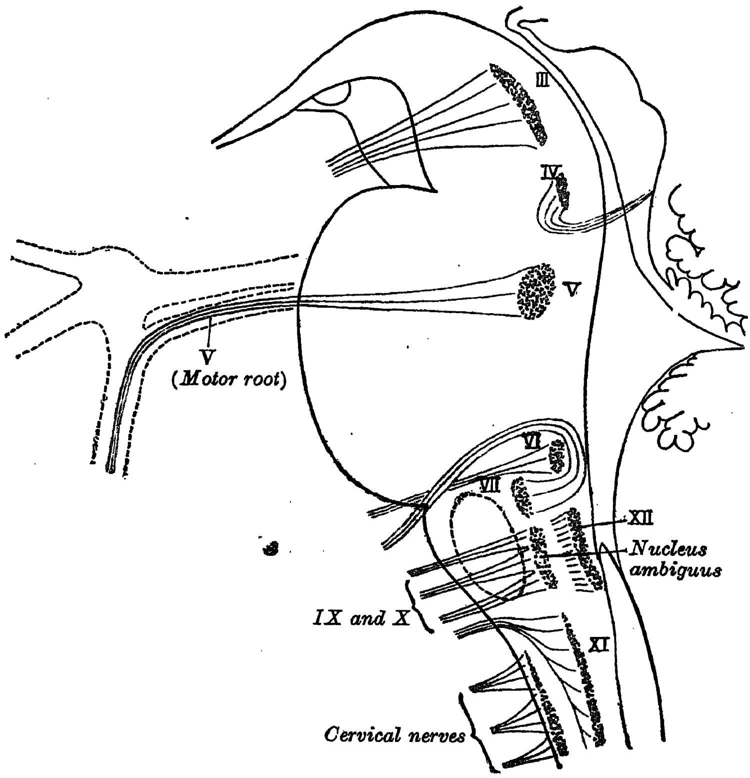
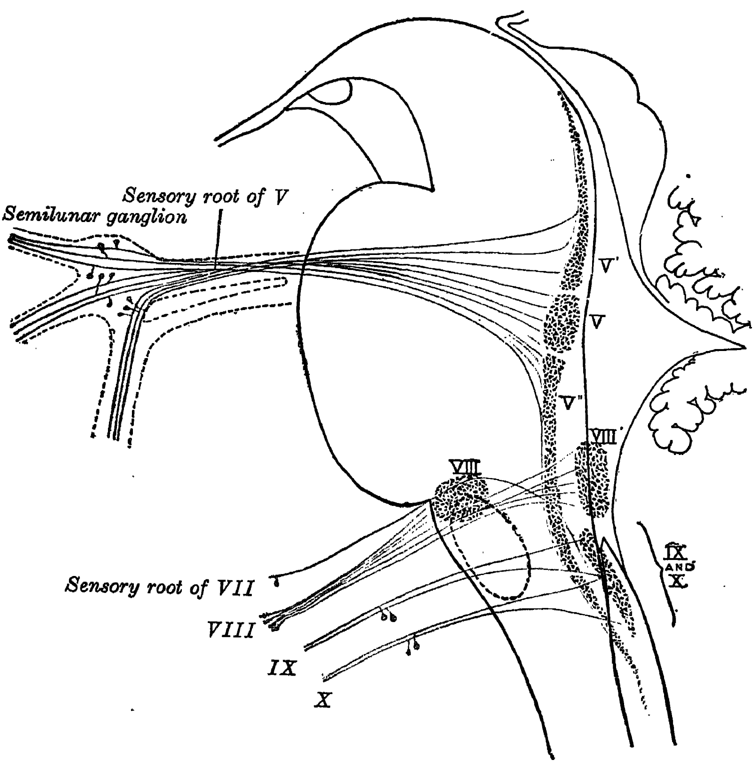


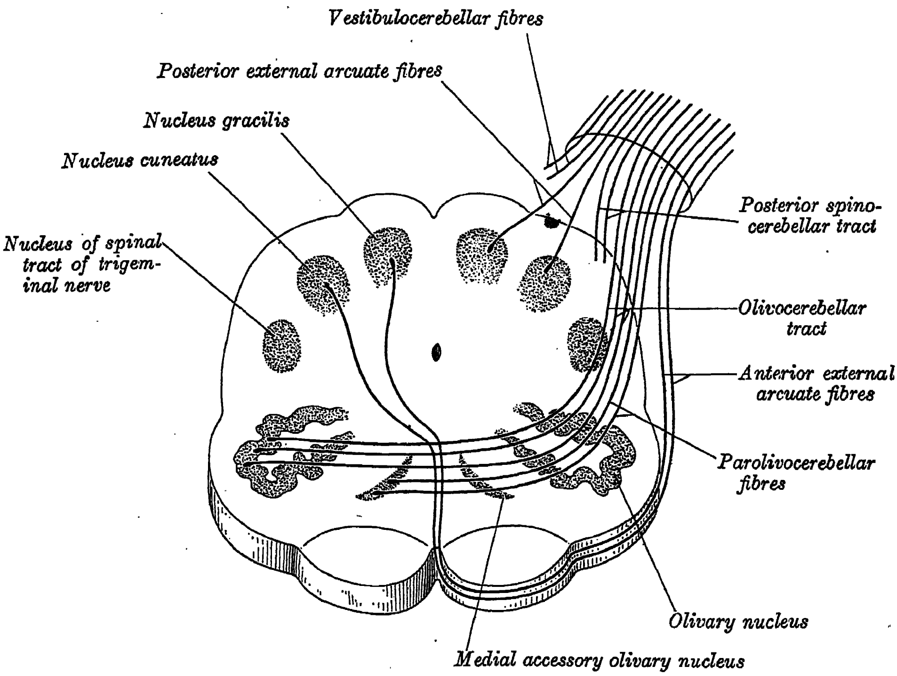
Fig. 848.—The primary terminal nuclei of the afferent (sensory) cranial nerves schematically represented. Lateral aspect. (The olfactory and optic centres are omitted.)



The nucleus of the tractus solitarius, the substantia gelatinosa and the nucleus ambiguus show little alteration in position. Near the upper end of the nucleus ambiguus a small collection of cells in the formatio reticularis constitutes the *inferior salivary nucleus*. The fibres which arise in this nucleus join the fila of the glossopharyngeal nerve and ultimately reach the parotid gland (p. 1068).

The arrangement of the white substance at this level shows no conspicuous alteration. The *inferior cerebellar peduncle* has increased in size and forms a well-marked elevation on the dorsilateral aspect of the medulla oblongata. Fibres from the olivary nucleus [olivocerebellar tract] and from the nucleus gracilis and the nucleus cuneatus of the opposite side [anterior external arcuate fibres] and the posterior spinocerebellar tract of the same side, have already been traced into it, and in addition it receives the *posterior external arcuate*

FIG. 849.—A scheme showing the constitution of the inferior cerebellar peduncle.



fibres which join it from the nucleus gracilis and the nucleus cuneatus of the same side (figs. 849 and 857).

The disposition of the medial lemniscus alters as it is traced upwards. Its ventral part widens and insinuates itself between the dorsal aspect of the pyramid and the narrowing upper end of the olivary nucleus. At the same time its dorsal part recedes from the tectospinal tract and the medial longitudinal bundle, with which it is in close relation at lower levels in the medulla oblongata.

THE PONS

The **pons**, or fore part of the hind-brain, is situated in front of the cerebellum. From its upper part the cerebral peduncles emerge, one on each side of the median plane. Behind and below, the pons is continuous with the medulla oblongata, but is separated from it in front and laterally by a transverse furrow in which the abducent, facial, and auditory nerves appear.

The *ventral* or *anterior surface* of the pons (fig. 836) is prominent, being markedly convex from side to side, less so from above downwards. It consists of transverse fibres arched like a bridge across the median plane, and gathered on each side into a compact mass which forms the middle cerebellar peduncle.

It rests upon the dorsum sellæ of the sphenoid bone and on the upper portion of the basilar part of the occipital bone, and is limited above and below by well-defined borders. In the median plane the anterior surface of the pons is marked by the shallow *sulcus basilaris* for the lodgement of the basilar artery; this sulcus is bounded on each side by an eminence caused by the descent of the cerebrospinal fibres through the substance of the pons. Lateral to these eminences, near the upper border of the pons, the trigeminal nerves make their exit, each consisting of a smaller, medial, motor root, and a larger, lateral, sensory root; vertical lines, drawn immediately lateral to the attachments of the trigeminal nerves, may be taken as the boundaries between the ventral surface of the pons and the middle cerebellar peduncles.

The *dorsal* or *posterior surface* of the pons, triangular in shape, is hidden by the cerebellum, and bounded laterally by the superior cerebellar peduncles; it forms the upper part of the floor of the fourth ventricle, with which it will be described (p. 940).

The surface distinctions between the medulla oblongata and the pons, which are present in all mammals but are accentuated in the anthropoid apes and man, are not discernible in lower vertebrates. Transverse sections through the pons in man show that it is readily subdivisible into a ventral and a dorsal portion. The ventral portion, which is termed the *basilar part*, contains bundles of longitudinal fibre, a great number of transverse fibres, and scattered collections of grey matter which constitute the *nuclei pontis*. The dorsal portion retains all the characteristic features of the medulla oblongata and is the true upward continuation of that structure. It contains representatives of the somatic efferent column, the branchial efferent column, the somatic afferent column and the auditolateral column. In addition, it is traversed by the medial lemniscus, the medial longitudinal bundle, the spinal lemniscus, the anterior spinocerebellar tract, the rubrospinal tract, etc., in fact, all the tracts which are passing from lower to higher or from higher to lower levels, with the single exception of the pyramidal tract.

The significance of the basilar part of the pons becomes clear when it is remembered that owing to the increased possibilities of movement in the mammalia, the mammalian cerebellum attains a vastly greater importance than it possesses in the nervous system of lower vertebrates. The complex movements of the mammalia demand perfect synergic control for their proper execution, and it is assured by the connexions which develop between the cerebral cortex and the neocerebellum, through the medium of the nuclei pontis. In man, large fibre tracts connect all the areas of the cerebral cortex with the nuclei pontis, where they are relayed to the cerebellum.

The basilar part of the pons is an expression of the importance of the effector apparatus as an index of evolutionary progress. The intimate relationship between visual and auditory impressions on the one hand and the movements involved in speech and writing on the other demand a rich connexion between the visual, auditory and motor areas of the cortex with the cerebellum. There is no need to multiply examples to illustrate that in the complexity of his movements man is far ahead of his nearest relations in the animal kingdom, and that, therefore, in man the basilar part of the pons attains its highest development.

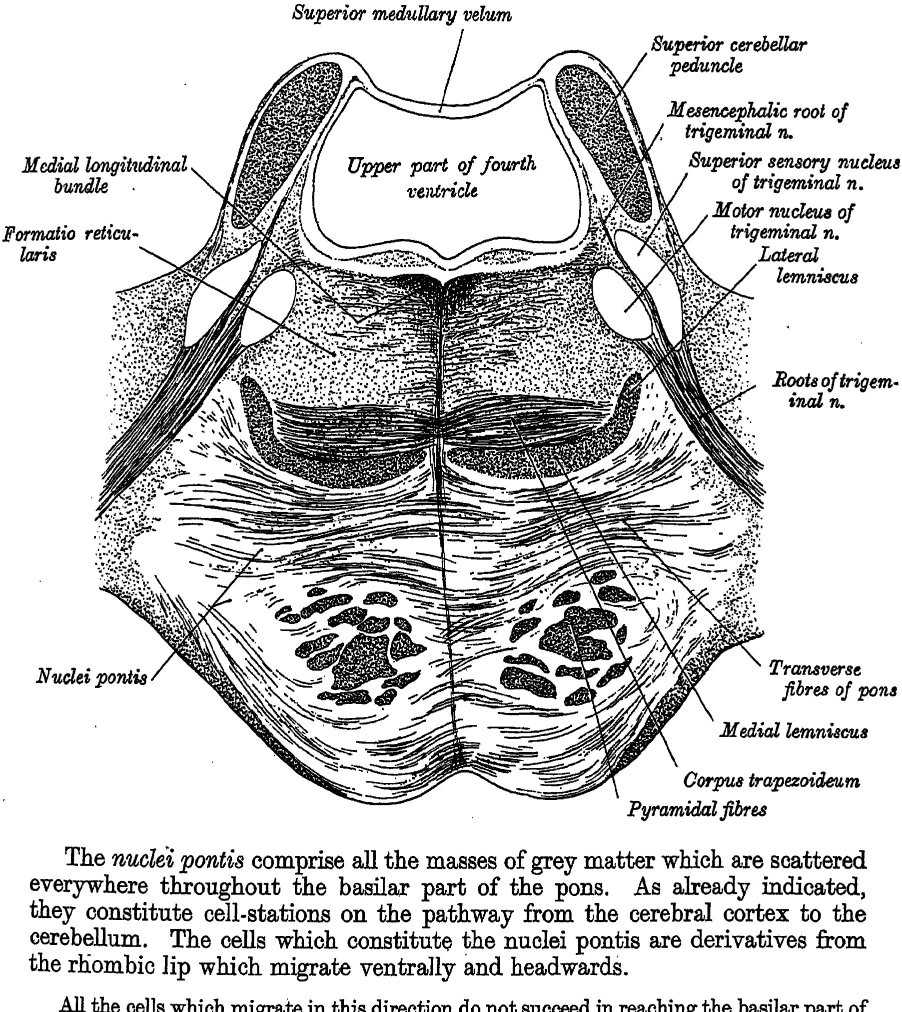
In the lowliest mammals, such as Echidna, the basilar part is present only in the region of the pons which lies above the attachment of the trigeminal nerve. Its enlargement in higher mammals is effected by its extension in a caudal direction. As a direct result of this extension, the sixth, seventh and eighth cranial nerves take their surface origin along its lower border.

Internal structure of the pons.—The *basilar part* presents a similar arrangement of its grey and white matter at all levels.

The *longitudinal bundles* comprise the cerebropontine and the important cerebrospinal (motor) fibres, which are continued downwards from the base of the cerebral peduncle. As they enter the upper limit of the basilar part of the pons, they form a compact collection of fibres, but they rapidly become broken up into numerous smaller bundles, separated from one another by the *nuclei pontis* and the transverse fibres of the pons. The *cerebrospinal fibres* descend

through the whole length of the pons and enter the pyramid of the medulla oblongata, where they form a compact tract (p. 914). In their course through the pons they give off fibres which run backwards, downwards and medially and cross the median plane to reach the motor nuclei of the fifth, sixth and seventh cranial nerves of the opposite side. The *cerebropontine fibres*, which are derived from the cerebral cortex, especially of the frontal, temporal and occipital regions, terminate at different levels in the nuclei pontis and are relayed as ponticerebellar fibres to the opposite cerebellar hemisphere (fig. 857). These latter form the transverse fibres of the pons and constitute nearly the whole of the middle cerebellar peduncle.

FIG. 850.—A coronal section through the upper part of the pons. (Semidiagrammatic. After Villiger.)



The *nuclei pontis* comprise all the masses of grey matter which are scattered everywhere throughout the basilar part of the pons. As already indicated, they constitute cell-stations on the pathway from the cerebral cortex to the cerebellum. The cells which constitute the nuclei pontis are derivatives from the rhombic lip which migrate ventrally and headwards.

All the cells which migrate in this direction do not succeed in reaching the basilar part of the pons. Some of them remain, forming an oblique ridge across the dorsilateral aspect of the inferior cerebellar peduncle, and constitute the *nucleus of the circumolivary bundle* (corpus pontobulbare). The fibres to which this discrete part of the nuclei pontis gives origin run vertically upwards on the surface between the emerging seventh nerve on the medial side, and its sensory root and the eighth nerve on the lateral side. The afferent fibres to the nucleus traverse the whole length of the pons with the cerebrospinal fibres and leave them only in the medulla oblongata. They course obliquely backwards and upwards over the surface of the olive, to reach their destination, forming the *fasciculus circumolivaris pyramidis* (fig. 856).

The *dorsal part* of the pons shows many differences in structure, in its lower and upper parts.

The areas not occupied by the central grey matter, the named nuclei and the principal fibre tracts constitute the formatio reticularis of the pons. It consists of scattered islets of grey matter, traversed by white fibres which are passing in all directions.

(A) The lower part of the tegmentum contains the somatic motor nucleus of the sixth cranial nerve, the branchial motor nucleus of the seventh cranial nerve, the auditolateral nuclei of the vestibular and cochlear divisions of the eighth nerve, and certain isolated collections of grey matter which will be referred to below.

The *medial nucleus* and the *inferior nucleus* of the vestibular nerve are continued upwards for a short distance into the tegmentum of the pons. The *lateral vestibular nucleus* is placed on the ventrilateral aspect of the medial nucleus, between it and the inferior cerebellar peduncle. This nucleus is characterised by the large size of its constituent cells, which is strongly suggestive of their motor character. Some of the fibres of the vestibular nerve are relayed in the lateral nucleus and emerge from its medial side. They turn downwards and descend through the pons and medulla oblongata to enter the anterior white column of the spinal cord, where they constitute the *vestibulospinal tract.* They end, uncrossed, by arborising round the dendrites of the large motor cells of the anterior grey column, and they clearly constitute the outgoing pathway for vestibulospinal reflexes.

The *superior vestibular nucleus* extends to a higher level in the pons than the other nuclei of the vestibular nerve. It is continuous with the upper end of the lateral nucleus and occupies the superolateral portion of the vestibular area. The fibres of the vestibular nerve which are relayed in this nucleus may pass to the cerebellum or to the medial longitudinal bundle, of which they form an important constituent.

The *ventral cochlear nucleus* is placed on the ventrilateral aspect of the inferior cerebellar peduncle (restiform body), as it passes upwards and laterally through the lower part of the pons. It receives afferent fibres from the cochlear nerve, and its outgoing fibres pass medially through the substance of the tegmentum and decussate with corresponding fibres of the opposite side. In this situation they constitute the *corpus trapezoideum* and they subsequently enter the lateral lemniscus. Small islets of grey matter are found amongst the fibres of the corpus trapezoideum, from which they receive fibres and collaterals. They send their efferent fibres into the lateral lemniscus and into the dorsal nucleus of the corpus trapezoideum (superior olive) (p. 923). These scattered collections of nerve-cells together form the *ventral nucleus of the corpus trapezoideum.*

The *dorsal cochlear nucleus,* which receives the remainder of the fibres of the cochlear nerve, lies on the dorsal aspect of the inferior cerebellar peduncle (restiform body) and forms the auditory tubercle (p. 941). The fibres to which its cells give origin course medially, lying immediately under the floor of the fourth ventricle and constituting the *auditory striæ* (striæ medullares).* On reaching the median sulcus they bend ventrally and cross the median plane, decussating obliquely with the corresponding fibres of the opposite side. Continuing in a ventrilateral direction they join the fibres of the corpus trapezoideum, and turn upwards with them to form the *lateral lemniscus* (p. 924). Some of the fibres from the dorsal cochlear nucleus take no part in the formation of the auditory striæ but run obliquely through the substance of the tegmentum to reach the lateral lemniscus of the opposite side.

The pathways followed by the second neurone fibres of the vestibular and cochlear nerves are not so sharply differentiated as might be supposed from the description given above. It would appear from the work of Winkler † and others that the vestibular nuclei (especially the lateral nucleus) contribute many fibres to the auditory striæ, the corpus trapezoideum and the lateral lemniscus, and that similar reflex movements may be induced both by vestibular and by cochlear stimulation (see also p. 949).

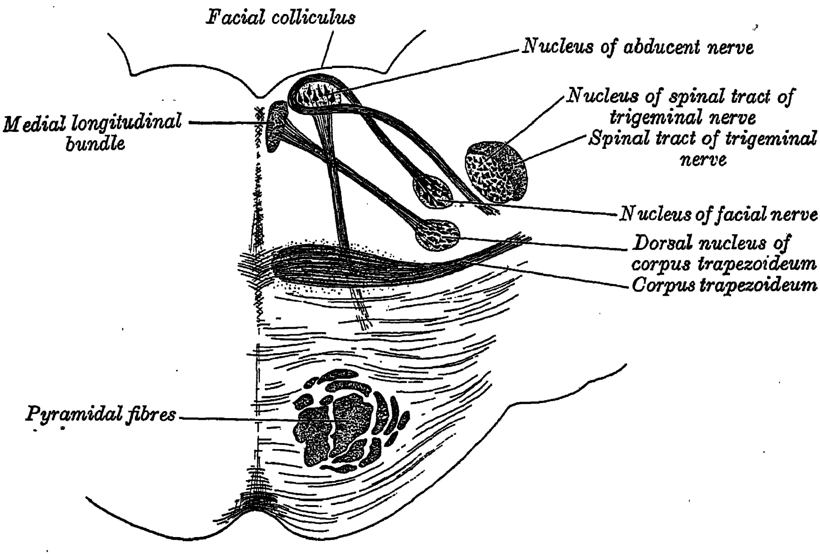
* It would appear that the striæ auditoriæ are formed by the external arcuate fibres and by fibres from the peduncle of the flocculus, as well as by fibres from the dorsal cochlear nucleus.

† Winkler, C., "The Central Course of the Nervus Octavus and its Influence on Motility." 1918. *Opera omnia*, vol. iv.

The *dorsal nucleus of the corpus trapezoideum* (superior olive) is a small nucleus which is closely related to the corpus trapezoideum in the ventrilateral part of the formatio reticularis. It receives collaterals from many of the second neurone fibres of the eighth nerve, and others of these fibres terminate in its substance. From its dorsal aspect a bundle of new fibres emerges and constitutes its *peduncle*. They pass to the medial longitudinal bundle (fig. 851), and so, probably, reach the motor nuclei of other cranial nerves and the inferior corpus quadrigeminum.

The *nucleus of the abducent nerve* lies in the central grey matter a short distance from the median plane. It is the representative at this level of the somatic efferent column, and it lies in line with the nuclei of the third and fourth cranial nerves, above, and the hypoglossal nerve, below. It is in close relation with the medial longitudinal bundle, which is placed to its ventrimedial side. In this way fibres from the vestibular and cochlear nuclei and the nuclei of other

FIG. 851.—Section through the left half of the pons, showing the course taken by the fibres of the facial nerve after leaving their nucleus of origin. Diagrammatic.



cranial nerves, especially the third nerve, have easy access to the sixth nucleus. It also bears an intimate relationship to the emerging fibres of the facial nerve (see below). The outgoing fibres of the sixth nerve pass ventrally and downwards through the formatio reticularis, intersecting the corpus trapezoideum and the medial lemniscus and traversing the basilar part of the pons to reach the surface at its lower border.

The *facial nucleus* lies in the ventrilateral part of the formatio reticularis of the pons, immediately dorsal to the dorsal nucleus of the corpus trapezoideum. Dorsal to it, and somewhat to its lateral side, lies the *spinal tract of the trigeminal nerve* and its associated nucleus. The facial nucleus receives fibres from the pyramidal tract of the opposite side and also a smaller number from the pyramidal tract of the same side. Its large motor cells give origin to the fibres of the facial nerve. These fibres do not pass directly from their origin to the surface of the pons, but pursue a very remarkable course. At first they incline dorsally and medially towards the floor of the fourth ventricle, where they come into relationship with the abducent nucleus (fig. 851). They then course upwards on the medial side of this nucleus, coming into close relationship with the medial longitudinal bundle, by means of which the seventh nerve may be brought into communication with the other cranial nerves. Finally, the fibres of the facial nerve curve forwards over the upper end of the sixth nucleus and pass forwards, laterally and downwards through the reticular formation.

In their course to the surface they pass between their own nucleus on the medial side and the nucleus of the spinal tract of the trigeminal nerve on the lateral side.

The unusual behaviour of the emerging fibres of the seventh nerve provides striking evidence in favour of the theory of neurobiotaxis (p. 911). In the 10 mm. human embryo the facial nucleus lies in the floor of the fourth ventricle, occupying the position of the branchial (special visceral) efferent column, and at this stage it is placed at a higher level than the abducent nucleus. As growth proceeds, the facial nucleus migrates at first caudally, dorsal to the sixth nucleus, and then ventrally to reach its adult position. As it migrates the axons to which its cells give rise elongate, and their subsequent course maps out the pathway along which the facial nucleus has travelled.

It must be remembered that the facial nucleus not only receives fibres from the pyramidal tracts for volitional control, but it also receives fibres from its own sensory root (through the nucleus of the tractus solitarius) and from the nucleus of the spinal tract of the trigeminal nerve. These latter sources of stimulation complete local reflex arcs, in every way similar to the segmental reflex arcs in the spinal cord. It is in an endeavour to retain its proximity to the nucleus of the tractus solitarius and to the nucleus of the spinal tract of the trigeminal nerve that the facial nucleus migrates from its original position in the basal lamina.

The *nucleus of the spinal tract of the trigeminal nerve* is continued up through the lower part of the pons, the fibres of the tract being closely applied to the lateral aspect of the nucleus. It is placed ventral to the lateral vestibular nucleus and is intersected by the fibres of the vestibular nerve which are destined for that nucleus. The inferior cerebellar peduncle (restiform body) lies to its lateral side below, but passes dorsally as it ascends to the cerebellum, and the spinal tract of the trigeminal nerve and its nucleus are subsequently related to the middle cerebellar peduncle.

In addition to most of the important tracts already studied at a lower level the white matter of the lower part of the tegmental region of the pons has the corpus trapezoideum, the lateral lemniscus and the emerging fibres of the sixth and seventh cranial nerves which are new elements not present in the upper part of the medulla oblongata.

The *medial lemniscus* occupies the ventral part of the tegmentum. Its outline, on transverse section, is a flattened oval, extending laterally from the median raphe. The vertically running fibres of the medial lemniscus are intersected by the horizontal fibres of the corpus trapezoideum. Laterally they are related to the *spinal lemniscus* and to the *trigeminal lemniscus*. The fibres of the latter are derived from the cells of the nucleus of the spinal tract of the trigeminal nerve of the opposite side, and they convey painful and thermal impressions from the skin of the face, the mucous membrane of the tongue, mouth, nose, etc.

The *corpus trapezoideum* is formed by the fibres which arise in the ventral cochlear nucleus. They run horizontally in the ventral part of the tegmentum, and, having intersected the vertical fibres of the medial lemniscus, they cross the median raphe, decussating with the corresponding fibres of the opposite side. Before they reach the emerging fibres of the seventh nerve the fibres of the corpus trapezoideum turn upwards to form the *lateral lemniscus*. In addition to the fibres from the ventral cochlear nucleus, the corpus trapezoideum is joined by the fibres which arise in the dorsal cochlear nucleus of the opposite side (p. 922).

The course of the outgoing fibres from the nuclei of the sixth and seventh cranial nerves has already been examined.

The *medial longitudinal bundle* lies close to the median plane, immediately ventral to the central grey matter. It is closely related to the nucleus of the abducent nerve and to the emerging fibres of the facial nerve, as they ascend on the medial side of that nucleus. The proximity of the fasciculus suggests that it may receive fibres from and transmit fibres to both structures (p. 949). As it lies in the lower part of the pons, the medial longitudinal bundle receives fibres from the medial and superior vestibular nuclei, the dorsal nucleus of the corpus trapezoideum (superior olive) (p. 923), and probably also from the

auditory striæ, with which it comes into close relation. These contributions from the eighth nerve form the greater part of the fasciculus (p. 949).

(B) The tegmental region of the upper part of the pons contains new elements in connexion with the trigeminal nerve, but otherwise shows no very noticeable alteration.

The somatic efferent column of the grey matter is unrepresented, but the branchial efferent column is represented by the important *motor nucleus of the trigeminal nerve*. It is separated from the lateral part of the floor of the fourth ventricle by a thin layer of central grey matter and by a part of the formatio reticularis pontis. The general splanchnic efferent and afferent columns are not represented in the pons, and so the trigeminal motor nucleus has its sensory nucleus—which represents the somatic afferent column—situated close to its lateral side. It receives fibres from the pyramidal tract of the opposite side and from the rubrospinal tract of the same side.

The *superior sensory nucleus of the trigeminal nerve* lies on the lateral side of its motor nucleus, intervening between it and the middle cerebellar peduncle. It receives the short ascending branches of the incoming sensory fibres of the trigeminal nerve and is continuous below with the nucleus of the spinal tract, which receives their long descending branches.

The sensory root of the trigeminal nerve, unlike the sensory roots of the other cranial nerves, contains fibres of both cutaneous and deep sensibility. Clinical evidence suggests that the fibres which terminate in the nucleus of the spinal tract convey crude painful and thermal (vital) sensibility, while the superior sensory nucleus receives the fibres conveying proprioceptive and discriminative (gnostic) sensibility. This view receives additional support from the phylogenetic history of the superior sensory nucleus. It is absent in fishes, although they possess a well-defined nucleus of the spinal tract. It is present, but of small size relatively, in amphibia and reptiles, and it is constantly present in the mammalia. It therefore shows a close parallel to the nucleus gracilis and the nucleus cuneatus.

In addition, clinical evidence tends to show that painful stimuli from the area innervated by the ophthalmic nerve enter the lowest part of the nucleus of the spinal tract; those from the maxillary nerve terminate in its middle part; and those from the mandibular nerve, in its upper part.

The *nucleus of the lateral lemniscus* is a small collection of cells placed on the medial aspect of the tract in the upper part of the pons. It receives collaterals and fibres from the lateral lemniscus, and some of its efferent fibres enter the medial longitudinal bundle.

The white matter of the tegmentum at this level is marked by the absence of the corpus trapezoideum, which is now replaced by the lateral lemniscus, and the invasion of its dorsilateral part by the superior cerebellar peduncles.

The *medial lemniscus* occupies a position in the ventral part of the tegmentum, but it has moved laterally a short distance from the median raphe. Laterally it is related to the *spinal lemniscus*, the *trigeminal lemniscus*, and to the *lateral lemniscus* and its nucleus. As the lateral lemniscus ascends, it passes dorsally and lies close to the surface. It will be seen subsequently to send its fibres into the inferior corpus quadrigeminum and the medial geniculate body. The *medial longitudinal bundle* retains its paramedian position.

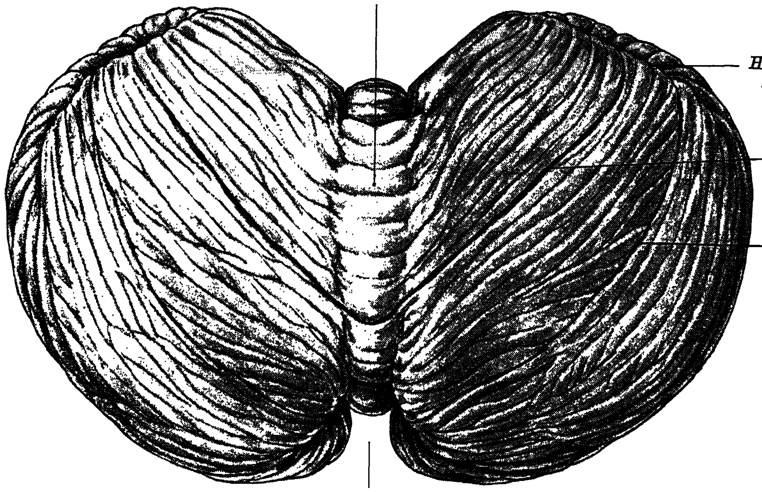
The *superior cerebellar peduncle* is formed by a large collection of fibres which take origin in the dentate nucleus of the cerebellum (p. 937), and pass upwards and forwards to enter the lateral part of the roof of the fourth ventricle. As it ascends in this position it inclines forwards and medially and enters the dorsilateral part of the tegmentum. The *anterior spinocerebellar tract* is intimately associated with the foregoing. It has already been traced up through the medulla oblongata, where it lies dorsal to the olivary nucleus and only separated from the surface by the anterior external arcuate fibres. In the lower part of the pons it inclines dorsally between the sensory nucleus of the trigeminal nerve and the middle cerebellar peduncle until it reaches the lateral aspect of the superior peduncle. Its fibres then curve downwards and backwards to enter the cerebellum.

THE CEREBELLUM

The **cerebellum**, the largest part of the hind-brain, lies behind the pons and medulla oblongata, and its median portion is separated from these structures by the cavity of the fourth ventricle. It lies in the inferior fossæ of the occipital bone and is covered by the tentorium cerebelli (p. 1024). It is somewhat ovoid in form, but constricted in its median part, and flattened from above downwards, its greatest diameter being from side to side. Its surface is not convoluted like that of the cerebrum, but is traversed by numerous curved furrows, which vary in depth at different parts and separate its constituent folia. Its average weight in the male is about 150 gms. In the adult the proportion between the cerebellum and cerebrum is about 1 to 8, in the infant about 1 to 20.

General form.—The cerebellum consists of a narrow median strip, termed the *vermis*, and two *cerebellar hemispheres*. On the *superior surface*, however, there is no attempt at subdivision in the sagittal or parasagittal planes, so that the superior vermis, which is raised into a slight median ridge, is directly continuous with the hemisphere on each side. Anteriorly the superior vermis

FIG. 852.—The cerebellum. Superior aspect. (Sharpey-Schafer.)



projects upwards beyond the free margin of the tentorium cerebelli, and from there it slopes downwards and backwards, related above to the straight sinus. The upper surface of each hemisphere is in contact with the tentorium cerebelli, and slopes downwards and laterally from the superior vermis. It is bounded, in front, by an anterolateral margin, which corresponds to the attachment of the tentorium cerebelli to the posterior border of the petrous part of the temporal bone, and behind, by a curved posterior margin, which abuts against the transverse sinus as it lies in the attached margin of the tentorium cerebelli.

On the *inferior surface* the cerebellar hemispheres are separated from each other by a deep hollow, which is termed the *vallecula*. The inferior surface of the hemisphere is irregularly convex and lies in contact with the posterior surface of the petrous part of the temporal bone, the sigmoid sinus, the mastoid part of the temporal bone and the lower part of the squamous portion of the occipital bone. The *inferior vermis* projects into the floor of the vallecula and is limited on each side by the *sulcus valleculæ*.

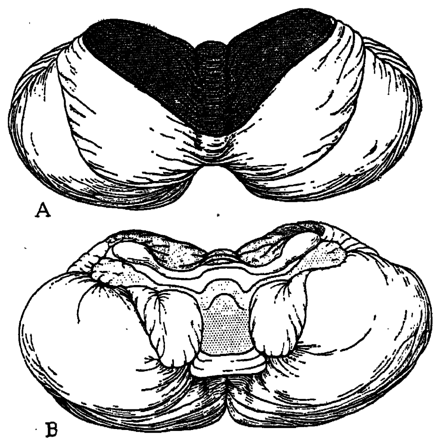
Anteriorly the cerebellum presents a wide, shallow notch, which lodges the pons and the upper part of the medulla oblongata, but these portions of the brain-stem are separated from it by the fourth ventricle. In the floor of the anterior cerebellar notch the peduncles pass into the white centre of the cerebellum.

Posteriorly the hemispheres are separated from each other by the posterior cerebellar notch, which is a deep and narrow interval, lodging the falx cerebelli of the dura mater.

SUBDIVISIONS OF THE CEREBELLUM

The nomenclature of the subdivisions of the cerebellum has undergone drastic revision in recent years and, owing to the researches of Bolk, Elliot Smith, Ingvar, Riley, Abbie and others, it is now possible to subdivide the cerebellum into areas which have the merit of possessing both an embryological and a morphological significance. Two lobes can be recognised, each consisting of a median and right and left lateral parts. They are separated by a deep fissure, termed the fissura prima, which crosses the whole width of the superior surface of the cerebellum and presents the outline of a widely open V (fig. 852). The portion of the cerebellum which lies in front of the fissura prima constitutes the anterosuperior (morphologically anterior) lobe. The portion which lies behind the fissura prima constitutes the postero-inferior (morphologically posterior) lobe; it includes not only the posterior part of the superior surface, but the whole of the inferior surface as well.

FIG. 853.—The lobes of the cerebellum.



A. Superior surface. B. Inferior surface. The anterosuperior lobe is shown in blue, and the postero-inferior lobe is uncoloured.

Superior surface.—The *anterosuperior lobe* forms rather less than one half of this surface. It is bounded in front by the anterior cerebellar notch and behind by the fissura prima, and includes a large part of the superior vermis. The remainder of this surface forms a part of the postero-inferior lobe. On each side the fissura prima reaches the anterolateral margin of the hemisphere, where it meets the middle cerebellar peduncle and cuts into the horizontal fissure. It is not continued round the anterolateral margin on to the inferior surface.

The part of the *superior vermis* which is included in the anterosuperior lobe is intersected by two short, but deep, transverse fissures, and is subdivided into three portions, termed the lingula, the central lobule and the lobulus culminis, in that order from before backwards. The *lingula* consists of a single lamella, which presents four or five poorly marked folia on its posterior aspect, while its anterior aspect is devoid of grey matter and is directly continuous with the white matter of the superior medullary velum (fig. 863). The *central lobule*, which is separated from the lingula by the *postlingual fissure*, is visible only on the anterior surface of the cerebellum; on each side it is continuous with the adjoining parts of the hemisphere, which are named the *alæ*. The *lobulus culminis* forms the whole of the median part of the anterosuperior lobe visible on the superior surface of the cerebellum. It is separated from the central lobule by the *postcentral fissure* and is limited behind by the fissura prima. On each side it is continuous with the adjoining parts of the hemisphere, which are termed the *anterior lunate lobules*.

The posterior part of the superior surface of the cerebellum is formed by the *postero-inferior lobe*. It includes a small portion of the superior vermis, which is divided into a *lobulus clivi* and a *lobulus folii*; the former adjoins the fissura prima. The large part of the superior surface of the hemisphere which belongs to this lobe is subdivided into two parts by a curved fissure, termed the *postlunate fissure*; it separates the *posterior lunate lobule* in front from the *superior surface of the ansiform lobule* behind.

The **inferior surface** of the cerebellum belongs entirely to the postero-inferior lobe: it includes the whole of the inferior vermis and the inferior aspect of each hemisphere. The *inferior vermis* is subdivided into four small portions, named, from before backwards, the nodule, the uvula, the pyramid and the lobulus tuberis. The *nodule*, which is intimately related to the fourth ventricle (*vide*

infra), is separated from the *uvula* by a short but deep transverse fissure, termed the *postnodular fissure*. A similar fissure, termed the *fissura secunda*, intervenes between the uvula and the *pyramid*, which is separated from the *lobulus tuberis* by the *postpyramidal fissure*.*

The inferior surface of the hemisphere is marked by a deep fissure, termed the *retrotonsillar fissure*, which passes laterally from the sulcus valleculæ opposite the fissura secunda and then curves forwards to gain the anterior aspect of the hemisphere. Together with the sulcus valleculæ it forms the boundaries of a circumscribed portion of the cerebellum, termed the *tonsil*, which is connected to the uvula across the floor of the sulcus valleculæ by a strip of cortex, termed the *furrowed band*. Superiorly the tonsil lies in intimate relation with the inferior surface of the inferior medullary velum. The large remaining part of the inferior surface of the hemisphere forms the *inferior surface of the ansiform lobule*, and the portion of it which lies lateral to the tonsil is connected to the lateral aspect of the pyramid across the floor of the sulcus valleculæ. The ansiform lobule is intersected by a deep fissure, named the *horizontal fissure*, which separates its inferior from its superior surface. In a general way this fissure follows the posterior and anterolateral borders of the hemisphere and its lips are separated in front by the middle cerebellar peduncle; it may appear on the superior surface of the cerebellum near the posterior cerebellar notch.

A small, partially detached portion of the cerebellum, termed the *flocculus*, lies immediately below the auditory nerve as it enters the brain-stem, and is crossed anteriorly by the fila of the glossopharyngeal and vagus nerves as they pass laterally to reach the jugular foramen. It is somewhat oval in outline, with a crenated margin, and from its medial end a narrow band of white fibres emerges, which constitutes the *peduncle* of the flocculus; it is covered anteriorly by the lateral recess of the fourth ventricle and the part of the choroid plexus which projects from the aperture of the recess (fig. 836).

The superior aspect of the nodule is directed towards the fourth ventricle. Anteriorly it is covered with grey matter and crossed by two or three shallow fissures. In this situation it is separated from the ventricular cavity by a double layer of pia mater and its contained choroid plexus, and the ventricular ependyma (fig. 863). Posteriorly the grey matter is deficient, and the white matter lies on the free surface, covered with a layer of neuroglia and the ventricular ependyma (fig. 863). The lateral aspect of the nodule is free anteriorly and is covered with grey matter; posteriorly, it presents a narrow strip, where its white core would be exposed, were it not directly continuous with the nervous layer of the inferior medullary velum.

The peduncle of the flocculus contains both afferent and efferent fibres. At the lateral angle of the floor of the fourth ventricle it divides into a dorsal and a ventral part. Through the dorsal part the flocculus establishes connexions with the cerebellar nuclei and the pyramid, and some fibres traverse the inferior medullary velum to reach the nodule and the uvula. The ventral part passes medially and turns upwards close to the lateral border of the pontine part of the floor of the fourth ventricle. Many of these fibres are afferent from the vestibular nuclei, but others are efferent and ascend to a higher level.†

Certain portions of the cerebellum are phylogenetically much older than the rest and constitute the *palæocerebellum*. They comprise the lingula in the antero-superior lobe, and the flocculi, the nodule and the uvula in the postero-inferior lobe. The appearance of higher motor centres in the neopallium (p. 973) called for increased cerebellar activity, and the demand was met by enlargement of certain portions of the vermis (lobulus culminis, lobulus clivi, lobulus folii and lobulus tuberis ‡) and by lateral extensions which formed the hemispheres. These therefore are more recent acquisitions and have become greatly expanded

* On morphological grounds this fissure is frequently termed the *prepyramidal fissure*.

† For a detailed description consult a paper by T. B. Johnston in the *Journal of Anatomy*, vol. lxviii., July, 1934.

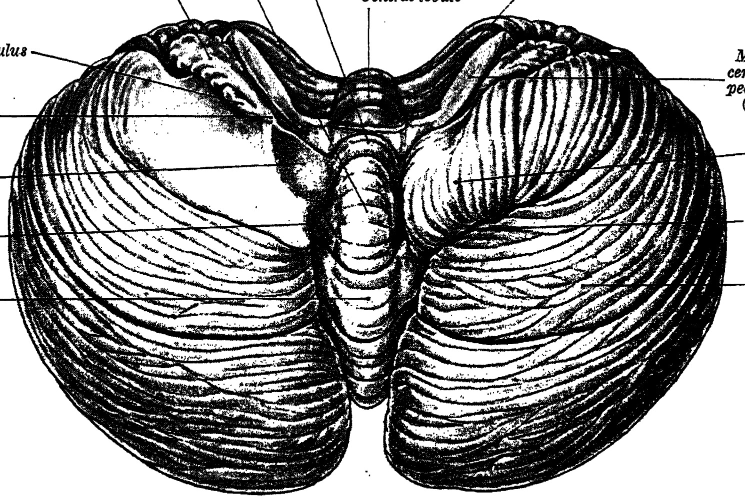
‡ According to Abbie the lobulus culminis receives, through the medium of the lower transverse fibres of the pons, numerous connexions from the temporal, parietal and occipital cortex, whereas the lobuli clivi, folii et tuberis receive similar connexions from the frontal cortex through the upper transverse fibres of the pons. For a detailed account, see *Phil. Trans. Series B. vol.* 115, *No. B.* 795, "The Projection of the Forebrain on the Pons and Cerebellum," by A. A. Abbie.

and elaborated in the mammalia and especially in the anthropoid apes and man. They are linked up freely with the cerebral cortex and constitute the *neo-cerebellum*, which has kept pace in its evolution with the growth of the basilar part of the pons and the growth of the olivary nucleus.

The superior (anterior) medullary velum is a thin lamina of white substance, which stretches between the superior cerebellar peduncles (brachia conjunctiva), and with them forms the roof of the upper part of the fourth ventricle; its deep surface is covered with the ventricular ependyma. The velum is narrow above, where it extends into the interval between the inferior corpora quadrigemina, and broader below, where it is continuous with the white substance of the superior vermis. The folia of the lingula are prolonged on to the dorsal surface of its lower half, and a median ridge, termed the *frenulum veli*, descends upon its upper part from between the inferior corpora quadrigemina. The trochlear nerves emerge at the sides of the frenulum (fig. 864).

The inferior (posterior) medullary vela form two thin, somewhat crescentic, sheets, placed one on each side of the nodule. Each consists of a thin layer of

FIG. 854.—The cerebellum. Inferior aspect. (Sharpey-Schafer.)



The tonsil and the adjoining part of the ansiform lobule of the right side have been removed.

white matter and neuroglia, covered on its upper aspect with the ventricular ependyma, and on its lower aspect with pia mater. Its superior surface forms the lower wall of the lateral dorsal recess of the fourth ventricle (p. 938); its inferior surface is related to the superior aspect of the tonsil. Its convex peripheral margin is continuous with the white core of the cerebellum and with the sides of the pyramid, uvula and nodule; its anterior (sometimes inferior) border is free (fig. 863) and from it the ventricular ependyma is prolonged downwards in close apposition with the pia mater to form the thin part of the roof of the ventricle and to reach the tæniæ. At its anterolateral corner the velum is continuous with the dorsal part of the peduncle of the flocculus, from which most, if not all, of its nerve fibres are derived.

Development of the Cerebellum

Early in the third month the cerebellum is represented by a mass which stretches across the roof of the upper part of the hind-brain vesicle and presents the appearance of a dumb-bell (fig. 145). Its narrow median part is destined to form the vermis, and its enlarged extremities develop into the hemispheres. As growth proceeds a number of transverse grooves appear on the dorsal aspect of the cerebellar rudiment, and give rise to the numerous fissures which characterise the surface of the cerebellum (fig. 854).

The first of these grooves demarcates the most caudal portion of the hemisphere, and is termed the *parafloccular fissure*. The parts which lie caudal to the fissure form the flocculus and the paraflocculus,* which is only a vestigial structure in the human brain. At first these structures constitute the most caudal part of the hemisphere, but, owing to the growth of the adjoining areas, they come to occupy the anterior part of the inferior surface in the adult. About the same period a small groove delimits the most caudal part of the vermis, which forms the nodule. This *postnodular fissure* is in line with the parafloccular fissure, and throughout life the nodule remains connected to the flocculus by the inferior medullary velum. Both these parts of the cerebellum are formed in close proximity to the line of attachment of the epithelial roof, i.e. to the rhombic lip (p. 112).

At the end of the third month a transverse furrow appears on the cephalic slope of the cerebellar rudiment, and deepens to form the *fissura prima*, which cuts into the vermis and both hemispheres, separating off the most headward portion of the rudiment to form the anterosuperior lobe of human anatomy (morphologically anterior lobe).

About the same period two short transverse grooves appear on the inferior vermis behind the postnodular fissure. The first of these is the *fissura secunda*, which demarcates the uvula, and the second is the *postpyramidal fissure*, which demarcates the pyramid (fig. 855). The whole cerebellum grows in a dorsal direction, and the caudal, or inferior, aspects of the hemispheres undergo much greater enlargement than the inferior vermis, which therefore becomes buried at the bottom of a deep hollow —the *vallecula*. While these changes are taking place numerous additional fissures develop, but they have little morphological significance. The most extensive of them forms the *horizontal fissure*.

THE INTERNAL STRUCTURE OF THE CEREBELLUM

The cerebellum exhibits a profound difference in structure from the spinal cord, the medulla oblongata and the pons, for the grey and white matter of which it is comprised are arranged in a precisely opposite manner. The grey matter is found covering the whole surface of the cerebellum and dipping in to line the various fissures which cross its surface. It is true that certain aggregations of grey matter are found in its interior, but that does not in any way alter the importance of the peripheral distribution of the grey matter as a whole, and the central arrangement of the white matter. In this way the cerebellum resembles the cerebrum, and it is this modification of the disposition of the grey matter which has rendered possible the enormous degree of expansion which these two parts of the nervous system have undergone during the process of evolution.

The **white matter** forms a central core, which is much thicker in the lateral parts than it is in the median area, where it forms a flattened strip connecting the enlarged lateral portions to each other. From its surfaces a series of nearly parallel plates or laminæ project towards the surface, and these give off secondary laminæ, usually more or less at right angles to the primary laminæ. In turn the secondary laminæ may give off still shorter laminæ, all of which are covered with grey matter. When a section is made through the cerebellum parallel to the median plane it divides the primary laminæ at right angles, and the cut surface presents a characteristic branched appearance which is termed the *arbor vitæ* (fig. 860).

The white matter of the cerebellum consists of (1) *fibriæ propriæ* and (2) *projection fibres*.

(1) The *fibræ propriæ* do not leave the cerebellum, but connect different cortical areas with one another. They may cross the median plane, and in that

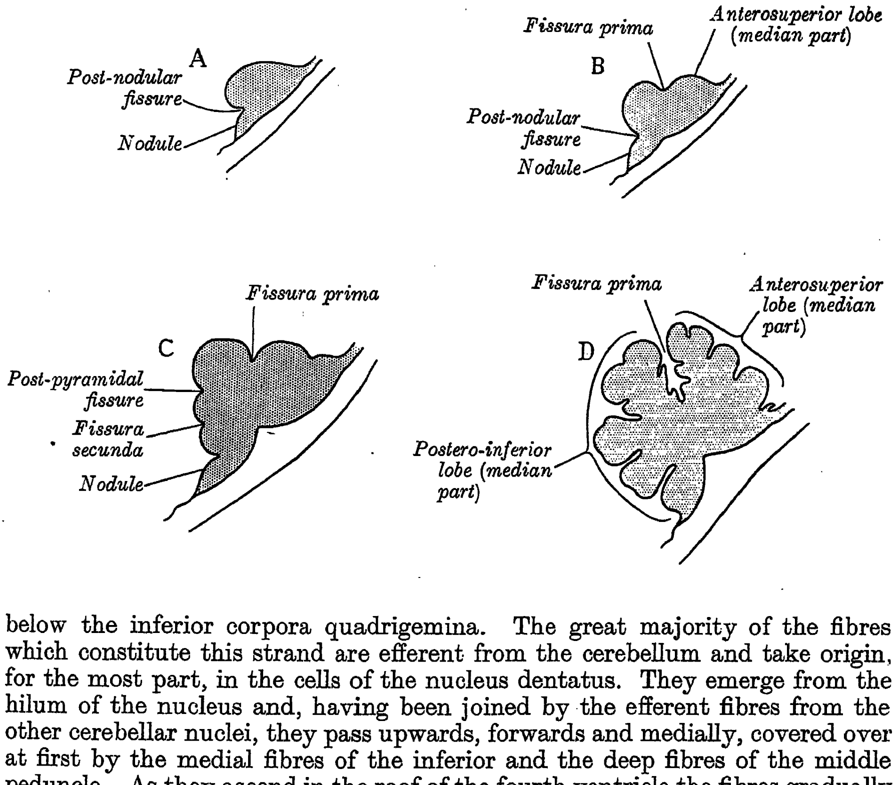
* In man the paraflocculus is represented by one or two small folia, placed on the inferior aspect of the middle cerebellar peduncle, close to the posterior margin of the flocculus, from which it is separated by a distinct fissure (fig. 854).

event they are termed *commissural fibres*, or they may be homolateral *association fibres*. The latter may pass between adjoining laminæ or they may extend from one area to another through the central white core.

(2) The **itinerant (projection) fibres** connect the cerebellum with other parts of the brain and the spinal cord. They are grouped together into three large bundles or *peduncles* on each side and these issue from the anterior cerebellar notch. The superior peduncles connect the cerebellum to the mid-brain, the middle peduncles connect it to the pons, and the inferior peduncles connect it to the medulla oblongata.

The **superior cerebellar peduncles** (brachia conjunctiva) emerge from the upper part of the anterior cerebellar notch and are hidden from view by the anterosuperior lobe of the cerebellum. When that structure is pulled aside they can be seen connected by the superior (anterior) medullary velum, and ascending in the lateral part of the roof of the fourth ventricle to disappear just

FIG. 855.—Median sagittal sections through the developing cerebellum, showing four different stages.



below the inferior corpora quadrigemina. The great majority of the fibres which constitute this strand are efferent from the cerebellum and take origin, for the most part, in the cells of the nucleus dentatus. They emerge from the hilum of the nucleus and, having been joined by the efferent fibres from the other cerebellar nuclei, they pass upwards, forwards and medially, covered over at first by the medial fibres of the inferior and the deep fibres of the middle peduncle. As they ascend in the roof of the fourth ventricle the fibres gradually incline forwards, and sink into the tegmental region of the mid-brain under cover of the lateral lemniscus. They then sweep medially to decussate with the corresponding fibres of the opposite side. After the decussation the fibres divide into ascending and descending branches. Most of the ascending branches end in the red nucleus, but some are continued upwards into the subthalamic region, where most of them end in the arcuate portion of the lateral nucleus of the thalamus. Others are said to proceed to the nuclei of the oculomotor and trochlear nerves. The descending branches can be traced downwards through the pons into the medulla oblongata and, according to Cajal, they are continued into the anterior and lateral white columns of the spinal cord. The red nucleus, through the rubrospinal tract, acts as the main distributing centre for efferent cerebellar impulses.

In addition to these efferent fibres the superior cerebellar peduncle contains the afferent fibres of the anterior spinocerebellar tract and a group of fibres

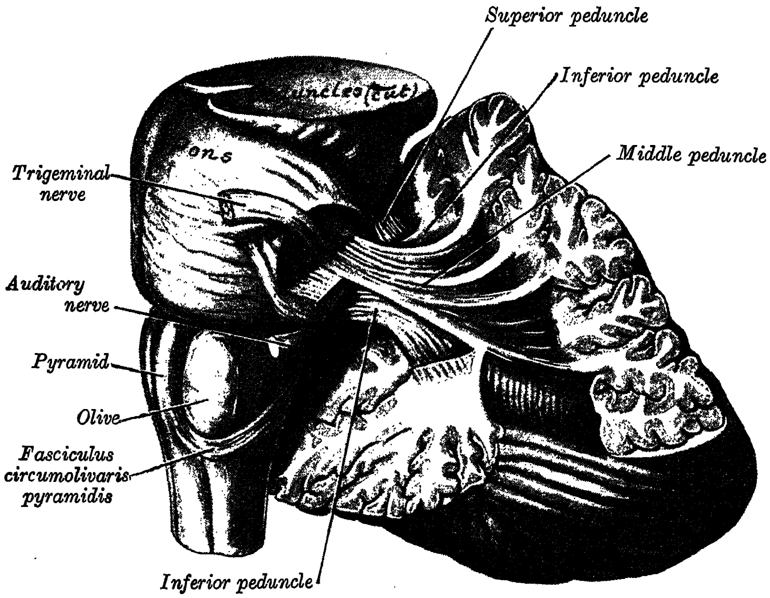
which take origin in the tectum of the mid-brain and constitute a tectocerebellar pathway for the passage of visual impulses to the cerebellum. These two afferent tracts utilise the peduncle as a convenient mode of access to the cerebellum.

The fibres of the anterior spinocerebellar tract ascend from the spinal cord (pp. 900 and 925), and terminate in the cortex of the superior vermis on both sides of the median plane.

The **middle cerebellar peduncles** (brachia pontis) (fig. 856) are largely composed of centripetal fibres, which arise from the cells of the nuclei pontis of the opposite side and end in the cortex of the cerebellar hemispheres (neocerebellum); they are said to contain also some efferent fibres to the nuclei pontis, and others to the spinal cord.

The fibres of each middle peduncle are arranged in three fasciculi, superior, inferior, and deep. The *superior* fasciculus is derived from the upper transverse fibres of the pons; it is directed backwards and laterally superficial to the other two fasciculi, and is distributed mainly to the lobules on the inferior surface of the cerebellar hemisphere, and to the parts

Fig. 856.—A dissection showing the projection fibres of the cerebellum. (E. B. Jamieson.)



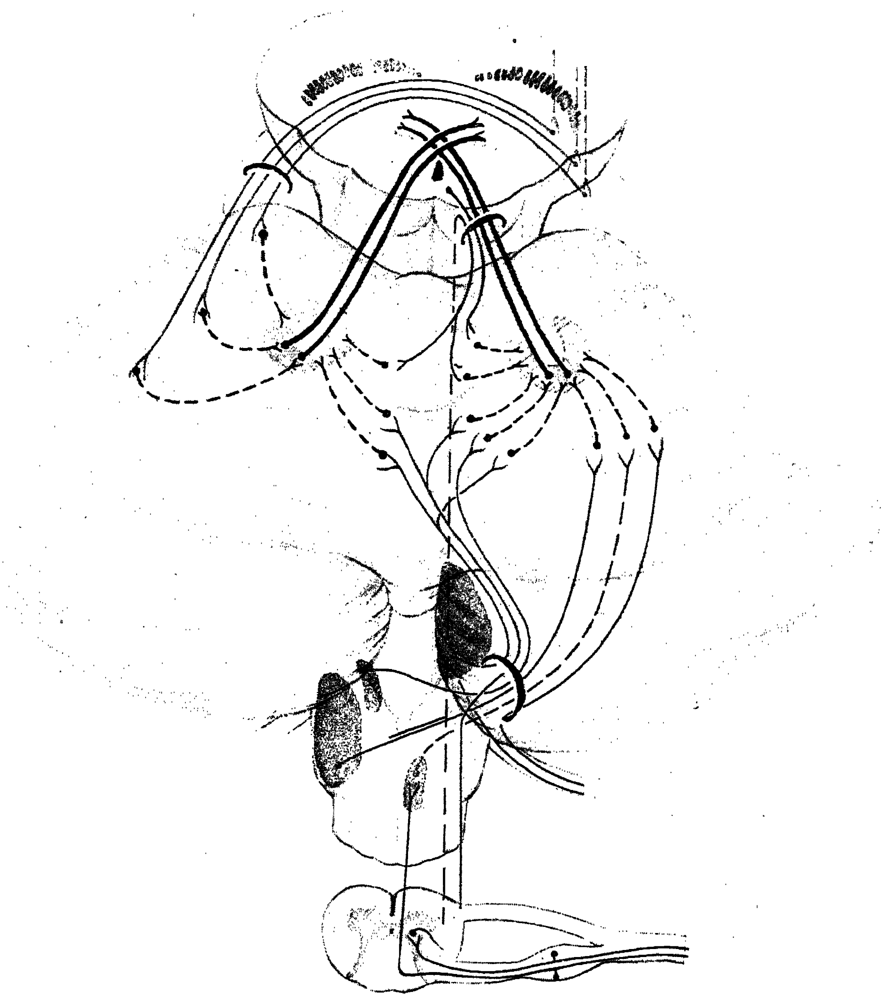
of the superior surface adjoining the posterior and lateral margins. The *inferior* fasciculus is formed by the lowest transverse fibres of the pons; * it passes under cover of the superior fasciculus and is continued downwards and backwards more or less parallel with it, to be distributed to the folia on the under surface close to the vermis. The *deep* fasciculus comprises most of the deep transverse fibres of the pons. It is at first covered by the superior and inferior fasciculi, but crossing obliquely it appears on the medial side of the superior, from which it receives a bundle; its fibres spread out and pass to the upper anterior cerebellar folia. The fibres of this fasciculus cover those of the inferior peduncle.

The **inferior cerebellar peduncle** (restiform body) forms a second large tract of afferent fibres to the cerebellum. It draws its constituent fibres from a variety of sources, and they come together on the dorsilateral aspect of the upper part of the medulla oblongata. At the anterior cerebellar notch the tract bends backwards abruptly and insinuates itself between the superior and the middle peduncles. Each inferior peduncle contains the following fasciculi: (1) the posterior spinocerebellar tract, which ascends uncrossed from the spinal cord, and terminates in the cortex of the vermis on both sides of the median

* See footnote ‡, p. 928.

plane * ; (2) the olivocerebellar tract from the olivary nucleus of the opposite side, which terminates for the most part in the cortex of the hemispheres ; (3) the parolivocerebellar fibres from the accessory olivary nuclei of the opposite side, which terminate in the cortex of the palæocerebellum. (4) The anterior external arcuate fibres from the nucleus gracilis and nucleus cuneatus of the opposite side ; (5) the posterior external arcuate fibres from the corresponding nuclei of the same side. Both these groups end in the cortex of the cerebellum, but

FIG. 857.—The connexions of the cerebellum. Diagrammatic.



The constituent fibres of the inferior cerebellar peduncle=*blue*: those of the middle peduncle =*red* ; those of the superior peduncle=*black*. The gracile, olivary, accessory olivary and vestibular nuclei are coloured blue ; the dentate and red nuclei are shaded.

their precise connexions have not been satisfactorily demonstrated. (6) Vestibular fibres, derived partly from the vestibular nuclei but largely from the vestibular division of the auditory nerve, occupy the medial part of the inferior cerebellar peduncle and terminate in the cerebellar cortex, including the flocculus ; (7) cerebello-vestibular fibres, which constitute an efferent pathway from the roof nuclei to the superior and lateral vestibular nuclei.

Grey matter.—The grey matter of the cerebellum is found in two situations : (1) on the surface, forming the cortex ; (2) as independent masses in the interior.

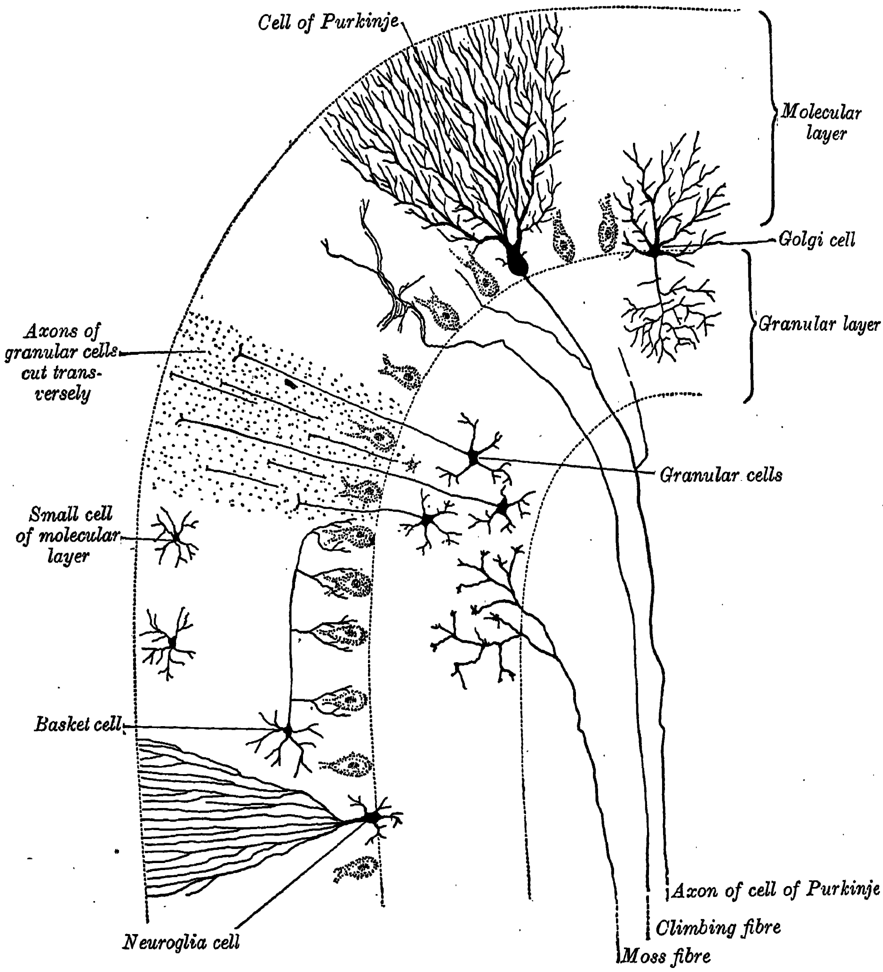
(1) The **grey matter of the cortex** presents a characteristic foliated appearance, due to the series of laminæ which project from the central white matter ;

* The fibres of the posterior spinocerebellar tract terminate in the vermis, but very few can be traced into the lobuli clivi, tuberis et folii. This distribution was demonstrated by Salisbury, McNulty and Horsley, and has recently been confirmed by Ingvar.

these in their turn give off secondary laminæ, which are covered by grey matter. Externally the cortex is covered with pia mater ; internally it rests on the white matter.

Throughout its whole extent the cerebellar cortex shows complete uniformity of structure. Local differences, which are so pronounced in the cerebral cortex, do not occur in the cerebellum, so that it is impossible to distinguish between sections taken from different areas. Not only is this the case in man, but it holds good throughout the vertebrate kingdom.

FIG. 858.—A transverse section through a cerebellar folium. Diagrammatic. (After Ramón y Cajal and Kölliker.)

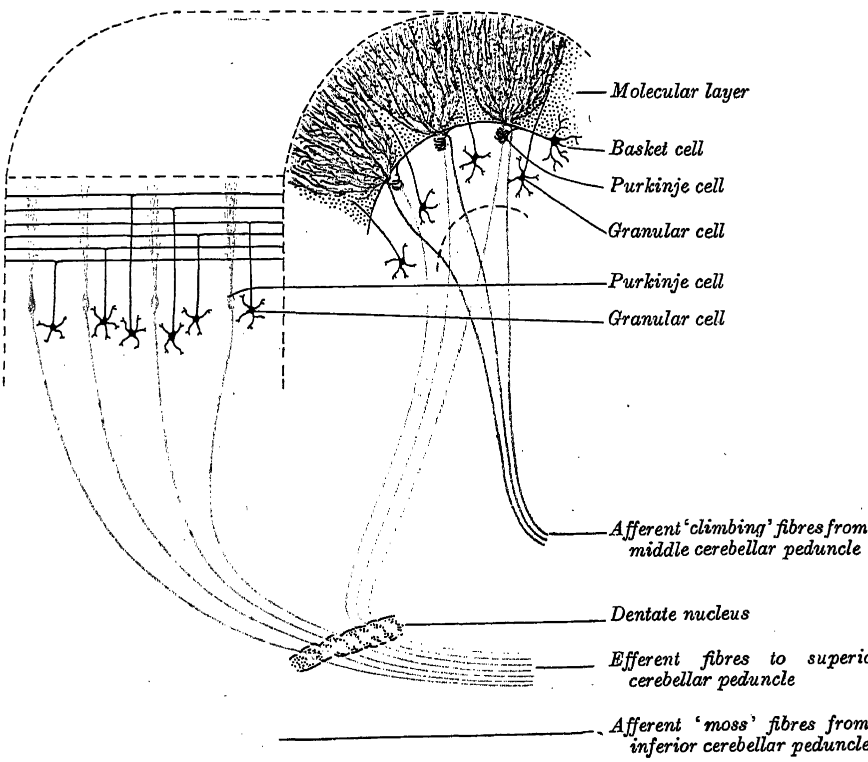


The cerebellar cortex consists of three layers, viz. an outer, molecular layer, an inner, granular layer and an intermediate, ganglionic layer formed by the large Purkinje cells.

The *molecular layer* comprises a large number of non-medullated nerve-fibres and two layers of nerve-cells. The nerve-fibres are derived from several sources. (*a*) The axons of the cells in the granular layer pass into the molecular layer where they divide at right angles, the individual branches passing right and left in the long axis of the folium. As these branches traverse the folium they come into contact association with the dendrites of a large number of Purkinje cells, and they are described as forming cruciate axodendritic synaptic connexions. (*b*) Fibres enter the molecular layer from the white matter of the cerebellum. They come into intimate relation with the dendrites of Purkinje's cells, breaking up into end filaments which follow the dendrites in their arbor-

isations (fig. 859). They are termed 'climbing fibres,' and Cajal regards them as the afferent fibres from the vestibular (in the palæocerebellum) and pontine nuclei (in the neocerebellum). (c) The dendrites and the collaterals of the axons of the cells of Purkinje, which will be referred to below. (d) The dendrites and fibres of the nerve-cells which lie within the molecular layer. In addition to these there are other fibres which have a vertical direction and are the processes of large neuroglia cells situated in the granular layer. They pass outwards to the periphery of the grey matter, where they expand into little conical enlargements, which form a sort of limiting membrane beneath the pia mater, analogous to the membrana limitans interna of the retina.

FIG. 859.—Schematic representation of the intracortical connexions of the cerebellar projection fibres.



In the right part of the figure a cerebellar folium is shown in transverse section; in the left part of the figure, the same folium is shown cut parallel with its long axis.
Blue: cells of Purkinje and their axons. *Red*: climbing fibres. *Orange*: 'moss' fibres.

The *cells of the molecular layer* are arranged in superficial and deep strata. The deep stratum contains large pyramidal cells, which have been termed the '*basket*' *cells*. Their dendrites and their axons extend in a sagittal direction, and the latter are clearly of great importance since they not only end by arborising around the body of a Purkinje cell, but they also give off collaterals which terminate in the same way. One basket cell may, through its axon, come into relationship with six or seven Purkinje cells (fig. 858). The superficial stratum consists of small pyramidal cells which, like the basket cells, send their dendrites and axons in a sagittal direction. Their axons terminate by establishing synaptic relationships with the dendrites of Purkinje's cells.

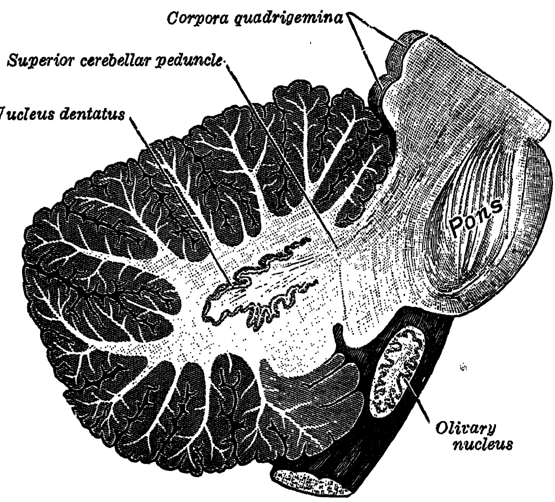
The *ganglionic layer* consists of *cells of Purkinje*, which are peculiar to the cerebellum; they form a single stratum of large, flask-shaped cells at the junction of the molecular and granular layers, their bases resting against the latter. The cells are flattened in a direction transverse to the long axis of a folium, and thus appear broad in sections carried across a folium, and fusiform in sections parallel to the long axis of a folium (fig. 859). From the neck of the flask one

or more dendrites arise and pass into the molecular layer, where they subdivide and form an extremely rich arborescence, the various subdivisions of the dendrites being covered by lateral spine-like processes. This arborescence, like the cell, is flattened at right angles to the long axis of a folium ; in other words, it resembles the branches of a fruit-tree trained against a trellis or a wall. Hence, in sections carried across a folium the arborescence is broad and expanded ; whereas in sections parallel to the long axis of a folium, the arborescence, like the cell, is seen in profile, and is limited to a narrow area (fig. 859).

From the bottom of the flask-shaped cell the axon arises ; this passes through the granular layer, and, becoming medullated, is continued as a nerve-fibre in the subjacent white matter. As it traverses the granular layer it gives off fine collaterals, some of which run into the molecular layer. The axons of the cells of Purkinje terminate in the deep nuclei of the cerebellum.

The *granular layer* (fig. 859) contains numerous small nerve-cells together with many nerve-fibres. The *granular cells*, which are the most abundant of

FIG. 860.—A sagittal section through the right cerebellar hemisphere. The right olive has also been cut sagittally.



the elements of the cerebellar cortex, are small and round, with relatively large nuclei. Each cell is provided with four or five dendrites, which radiate out from it and end close to the cell body in fine terminal tufts. The axons of the granular cells have already been described in the molecular layer.

Many fibres enter the granular layer from the white substance of the cerebellum. Some merely pass through it on their way to the molecular layer (climbing fibres), but others end in the granular layer by dividing into numerous branches, on which peculiar moss-like appendages can be seen. They are termed *moss fibres*, and they end by forming synaptic connexions with the dendrites of the granular layer. According to Cajal these fibres are derived from the inferior cerebellar peduncle and especially from the spinocerebellar and olivocerebellar tracts.

Apart from the homogeneity of the cortex, the most striking feature of the minute anatomy of the cerebellum is the provision which is made for the simultaneous discharge of the impulses transmitted by the basket and granular cells into a large number of Purkinje cells. As each 'moss' fibre discharges into several granular cells; the number of Purkinje cells which can be stimulated by one 'moss' fibre is considerably magnified. It will be remembered that the Purkinje cells constitute the first neurone on the efferent pathway from the cerebellum, and this arrangement therefore provides a mechanism whereby an afferent impulse is able to bring about a widely distributed response.

(2) **The independent centres of grey matter** are imbedded in the white matter of the cerebellum and are four in number on each side : one is of large size,

and is known as the nucleus dentatus; the other three, much smaller, are situated near the middle of the cerebellum, and are known as the nucleus emboliformis, nucleus globosus, and nucleus fastigii. These nuclei receive the axons of the cells of Purkinje, and they therefore constitute cell stations on the efferent pathways from the cerebellar cortex.

The *nucleus dentatus* (fig. 860) is situated a little to the medial side of the centre of the stem of the white matter of the hemisphere. It consists of an irregularly folded grey lamina, containing a white centre and presenting, on its anteromedial aspect, an opening, termed the hilum, from which most of the fibres of the superior cerebellar peduncle (brachium conjunctivium) emerge (p. 931).

The *nucleus emboliformis* lies close to the medial side of the nucleus dentatus, and partly covering its hilum. The *nucleus globosus*, an elongated mass, lies on the medial side of the nucleus emboliformis, and is directed anteroposteriorly. The *nucleus fastigii*, somewhat larger than the other two, is situated close to the median plane in the anterior part of the superior vermis. All these nuclei lie in the upper wall of the lateral dorsal recess of the fourth ventricle (p. 938) and are separated from its cavity by a thin layer of white matter.

It may be noted that, whereas electrical stimulation of the cerebellar cortex produces no visible response, electrical stimulation of the dentate nucleus causes movements which vary in their site and character with the particular part of the nucleus stimulated, the different parts of the body being definitely associated with specific areas of the nucleus.

The Functional Significance of the Cerebellum

The cerebellum differs from the portions of the central nervous system which have been examined hitherto in showing no sign of segmentation at any stage of its development. It is entirely a suprasegmental structure, which presumbly took over functions previously carried out in the individual segments of the spinal cord.

Its outstanding feature, and one that differentiates it from all other parts of the central nervous system, is the homogeneity of the structure of its cortex. In the cerebral cortex it has been possible to map out a number of areas which show differences in structure (p. 988), and it has been demonstrated in many instances that differences in structure are associated with differences in function. Accordingly there is good ground for supposing that the influence which the cerebellum exerts on the motor apparatus can be referred to one function only. The experimental and clinical evidence, though sometimes contradictory, tends on the whole to show that the cerebellum exerts a controlling and regulating influence over muscle tone, the word 'tone' being used in its broadest sense. Luciani summed up the cardinal symptoms of cerebellar disease as 'Atonia, Asthenia and Astasia,' but it is certainly probable that the asthenia can be ascribed to loss of tone in the actively contracting muscle groups, and not unlikely that the astasia may be attributed to loss of tone in the antagonistic groups.

The cells which form the cerebellum in the embryo migrate from the rhombic lip and especially from the region of the vestibular nuclei, but this intimate relationship with the equilibratory centres does not necessarily mean more than that the muscular movements concerned in equilibratory reflexes demand corresponding adjustments of muscle tone, which are carried out by the cerebellum. The part which the cerebellum plays in muscular co-ordination and in synergic control is probably also attributable to its control and regulation of muscle tone.

Functional localisation.—Of recent years many attempts have been made to demonstrate the association of definite areas of the cerebellum with individual parts of the body. The enormous elaboration of the neocerebellum in mammals at once suggests its association with the complicated, unilateral movements of the individual limbs, while the palæocerebellum would, on the same grounds, be associated with the movements of the head, neck and trunk and the automatic associated movements of the limbs. To a certain extent this can be said to be

borne out both by experimental and by clinical evidence, but only in a very broad and general way. In lesions confined to the superior vermis falling forwards is a striking symptom, indicating a loss of tonus in the extensor muscles of the trunk and head. In lesions confined to the inferior vermis the striking feature is falling backwards, indicating a loss of tonus in the flexor muscles. Gordon Holmes, however, has found that it is impossible to localise a small cerebellar lesion by studying the muscle groups affected, for in every case, and independent of the size of the lesion, he has found alterations in more than one part of the body. Nevertheless, it would appear that certain regions do exercise a general but not exclusive dominance over certain parts of the body.

A different type of cortical localisation, the importance of which cannot yet be appreciated fully, has been worked out by Gordon Holmes and Grainger Stewart. They found that definite areas of the olivary nucleus are associated with definite areas of the cerebellar cortex of the opposite side. They showed that the accessory olives and the upper and medial portion of the olivary nucleus are associated with the vermis, while the much larger, lower part of the olivary nucleus is associated with the hemisphere, not in a general way but in a very particular manner, definite portions of the nucleus being associated with quite circumscribed areas of the cerebellar cortex. This work has been confirmed by Brouwer in his study of cases of neocerebellar atrophy. The comparative study of the olivary nucleus is in perfect harmony with these findings, for the greater part of it develops *pari passu* with the development of the ventral part of the pons and the cerebellar hemispheres. What this close relationship connotes will only be determined when the connexions of the olivary nucleus have been more fully studied and elucidated.

The Fourth Ventricle (figs. 861—864)

The **fourth ventricle**, or cavity of the hind-brain, is a somewhat lozenge-shaped space situated in front of the cerebellum, and behind the pons and upper half of the medulla oblongata. Developmentally considered, it consists of three parts: a *superior* belonging to the isthmus rhombencephali, an *intermediate*, to the metencephalon, and an *inferior*, to the myelencephalon. It is lined with ciliated epithelium, and its inferior angle is continuous with the central canal of the medulla oblongata; its superior angle is continuous with the aqueduct of the mid-brain, which opens above into the cavity of the third ventricle. From its middle part a narrow, curved pouch, named the *lateral recess*, is prolonged on each side between the inferior cerebellar peduncle and the peduncle of the flocculus, and reaches as far as the medial part of the flocculus itself. It is crossed anteriorly by the fila of the glossopharyngeal and vagus nerves. The lateral extremity of the recess is open, allowing a portion of the choroid plexus of the fourth ventricle to protrude into the subarachnoid space (fig. 836). In the median plane the cavity extends dorsally into the white core of the cerebellum, forming a *dorsal median recess* (fig. 861) above the nodule, and on each side a *lateral dorsal recess* extends backwards still further (fig. 906), lying below the cerebellar nuclei, from which it is separated by a thin layer of white matter.

The fourth ventricle possesses lateral boundaries, a roof or dorsal wall, and a floor or ventral wall (rhomboid fossa).

Lateral boundaries.—The lower part of each lateral boundary is constituted by the gracile tubercle (clava), the fasciculus cuneatus, and the inferior cerebellar peduncle (restiform body); the upper part, by the superior cerebellar peduncle.

The **roof or dorsal wall** (fig. 862).—The upper portion of the roof is simple, and is formed by the superior cerebellar peduncles (brachia conjunctiva) and the superior medullary velum. The lower portion is more complicated; it is formed by: (1) the posterior part of the upper surface of the nodule, which is devoid of grey matter, (2) the inferior medullary vela, (3) the ventricular ependyma, covered with the tela chorioidea inferior, (4) the tæniæ of the ventricle, and (5) the obex.

The *superior cerebellar peduncles* (p. 931), on emerging from the central white matter of the cerebellum, pass upwards and forwards, forming at first

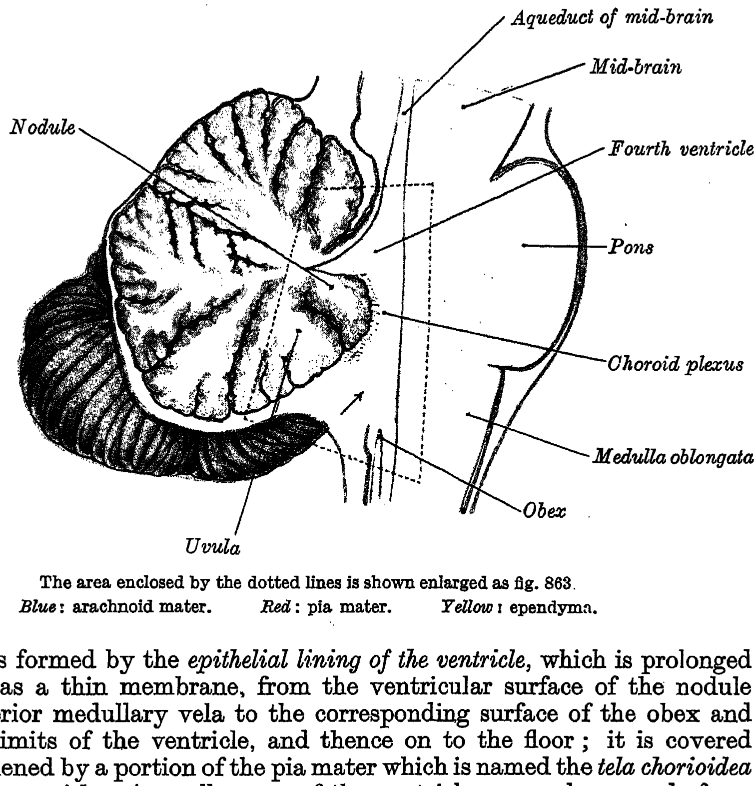
the lateral boundaries of the upper part of the ventricle ; on approaching the inferior corpora quadrigemina, they converge, and their medial portions overlap the ventricle and form part of its roof.

The *superior* (*anterior*) *medullary velum* (p. 929) fills the angular interval between the superior cerebellar peduncles, and is continuous behind with the central white matter of the cerebellum ; it is covered on its dorsal surface by the lingula of the superior vermis (fig. 863).

The nodule (p. 927) and the inferior medullary vela (p. 929) have already been described in detail.

Below the free margin of the inferior medullary velum on each side, and over the anterior part of the nodule in the median plane, the roof of the ventricle is devoid of nervous matter except in the immediate vicinity of the lower lateral boundaries of the ventricle, where two narrow white bands, termed the *tæniæ of the fourth ventricle*, appear ; these bands meet over the inferior angle of the ventricle in a thin triangular lamina, named the *obex*. The non-nervous part

FIG. 861.—Sagittal section through the brain-stem and the cerebellum close to the median plane. Diagrammatic. The arrow is in the median aperture of the fourth ventricle.



The area enclosed by the dotted lines is shown enlarged as fig. 863.
Blue: arachnoid mater. *Red*: pia mater. *Yellow*: ependyma.

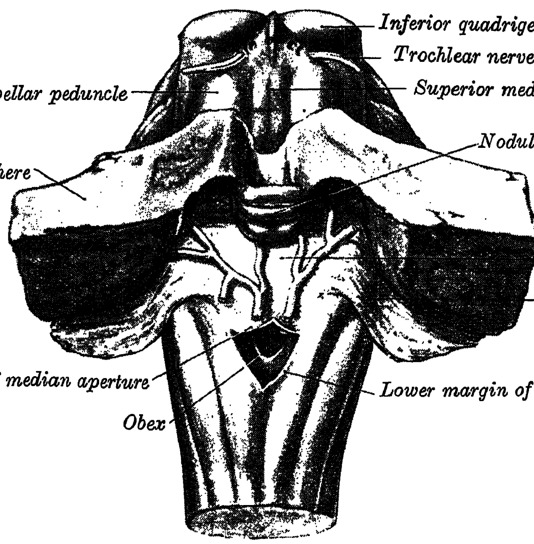
of the roof is formed by the *epithelial lining of the ventricle*, which is prolonged downwards as a thin membrane, from the ventricular surface of the nodule and the inferior medullary vela to the corresponding surface of the obex and the lateral limits of the ventricle, and thence on to the floor ; it is covered and strengthened by a portion of the pia mater which is named the *tela chorioidea of the fourth ventricle*. A small recess of the ventricle passes downwards for a short distance behind the obex (fig. 861), which is thus separated from the pia mater ascending from the posterior aspect of the medulla oblongata.

The *obex* is a thin, triangular, grey lamina, which covers the lower angle of the ventricle and is attached by its lateral margins to the gracile tubercle. It is covered with ependyma on both its anterior and posterior surfaces. The *tela chorioidea of the fourth ventricle* is the name applied to the fold of pia mater which is carried upwards between the cerebellum and the medulla oblongata. It consists of two layers, which are continuous with each other above, and are more or less adherent throughout. The posterior layer covers the antero-inferior surface of the cerebellum, while the anterior is applied to the structures which form the lower part of the roof of the ventricle, and is continuous inferiorly with the pia mater on the inferior cerebellar peduncles and the lower part of the medulla.

The openings in the roof.—In the roof of the fourth ventricle there are three openings, a median and two lateral. The *median aperture* is a large opening, situated below the nodule (fig. 862); it varies considerably in its extent and its irregular upper border is drawn backwards towards the inferior vermis in a somewhat funnel-shaped manner (fig. 863). The *lateral apertures* are placed at the ends of the lateral recesses and they are partly occupied by portions of the choroid plexus, which protrude into the subarachnoid space (fig. 836). Through these openings the ventricular cavity communicates with the subarachnoid space, and the cerebrospinal fluid can circulate from the one cavity to the other. Occasionally one of the lateral recesses may fail to open into the subarachnoid space, but the median aperture is constantly present.

The choroid plexuses.—Two highly vascular fringe-like processes of the tela chorioidea contain the choroid plexuses of the fourth ventricle; they invaginate the lower part of the roof of the ventricle and are everywhere covered by the epithelial lining of the cavity. Each consists of a vertical and a horizontal

Fig. 862.—The roof and the lateral recesses of the fourth ventricle exposed from behind.



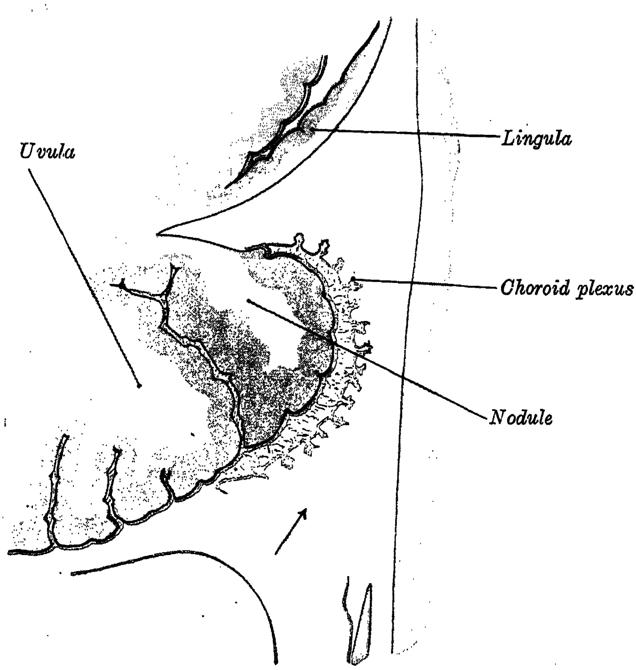
portion: the former lies close to the median plane, and the latter passes into the lateral recess and projects through the lateral aperture still covered by ependyma. The vertical parts of the plexuses are distinct from each other, but the horizontal portions are joined in the median plane; and hence the entire structure presents the form of the letter T, the vertical limb of which, however, is double. Numerous small tufts of the plexus are associated with the drawn-back upper wall of the median aperture and project into the subarachnoid space (fig. 863), like the tufts which protrude from the foramina of the lateral recesses.

The floor of the fourth ventricle (rhomboid fossa) (fig. 864).—The anterior wall or floor of the fourth ventricle is rhomboidal in shape; it is formed by the posterior surfaces of the pons and medulla oblongata. It is covered by a layer of grey matter continuous with that surrounding the central canal of the medulla oblongata and spinal cord; superficial to this there is a thin lamina of neuroglia covered with a layer of ciliated epithelium, which constitutes the *ependyma* of the ventricle. The floor consists of three parts, superior, intermediate and inferior. The *superior* part is triangular in shape and limited laterally by the superior cerebellar peduncles; its apex, directed upwards, is continuous with the aqueduct of the mid-brain; its base is represented by an imaginary line at the level of the upper ends of two small depressions, named the superior foveæ. The *intermediate* part extends from this level to that of the horizontal portions of the tæniæ of the ventricle and is prolonged into the lateral

recesses. The *inferior* part is triangular, and its downwardly directed apex is continuous with the wall of the central canal of the closed part of the medulla oblongata.

The floor of the fourth ventricle is divided into symmetrical halves by a *median sulcus*, which reaches from its upper to its lower angle and is deeper below than above. On each side of this sulcus there is an elevation, termed the *medial eminence*, bounded laterally by a sulcus which represents the *sulcus limitans* and separates the basal from the alar lamina. In the superior part of the floor the medial eminence has a width equal to that of the corresponding half of the floor, but opposite the superior fovea it forms an elongated swelling, named the *facial colliculus*, which overlies the nucleus of the abducent nerve, and is in part produced by the ascending portion of the root of the facial nerve. In the inferior part of the fossa the medial eminence assumes the form of a triangular

FIG. 863.—The relationship of the nodule to the fourth ventricle.



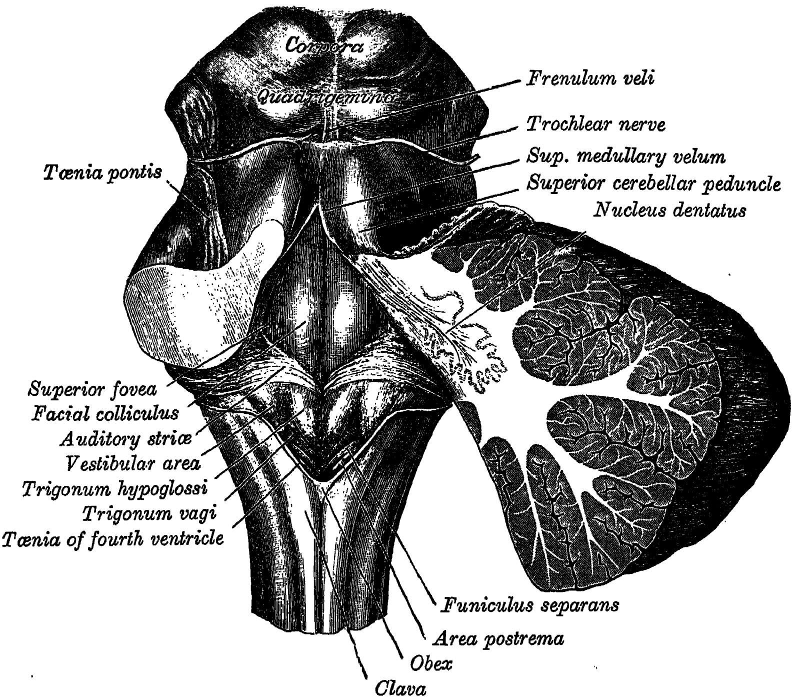
Blue: arachnoid mater. *Red*: pia mater. *Yellow*: ependyma.
The arrow is placed in the median aperture of the fourth ventricle.

area, termed the *hypoglossal triangle* or *trigonum hypoglossi*. When examined under water with a lens the hypoglossal triangle is seen to consist of a medial and a lateral area separated by a series of oblique furrows; the medial area corresponds with the upper part of the nucleus of the hypoglossal nerve, the lateral with a small nucleus, termed the *nucleus intercalatus*.

The *sulcus limitans* forms the lateral boundary of the medial eminence. Its superior part corresponds with the lateral limit of the floor and presents a bluish-grey area, named the *locus cæruleus*, which owes its colour to a patch of deeply pigmented nerve-cells, termed the *substantia ferruginea*. At the level of the colliculus facialis the sulcus limitans widens into a flattened depression, termed the *superior fovea*, and in the inferior part of the floor appears as a distinct dimple termed the *inferior fovea*. Lateral to the foveæ there is a rounded elevation named the *vestibular area* (area acustica), which extends into the lateral recess where it forms the *auditory tubercle* (p. 922). Winding round the inferior cerebellar peduncle and crossing the vestibular area and the medial eminence are a number of white strands, most of which are derived from the dorsal nucleus of the cochlear nerve. They are termed the *auditory striæ* (striæ

medullares), and disappear into the median sulcus (p. 941). Below the inferior fovea, and between the hypoglossal triangle and the lower part of the vestibular area a triangular dark field, named the *vagal triangle* or trigonum vagi, overlies the dorsal nucleus of the vagus nerve (p. 913). The lower part of the vagal triangle is crossed by a narrow translucent ridge, often named the *funiculus*

FIG. 864.—The floor of the fourth ventricle.



separans, and between this funiculus and the gracile tubercle (clava) is a small tongue-shaped area, which is often termed the *area postrema*. On section it is seen that the funiculus separans is formed by a strip of thickened ependyma, and the area postrema by loose, highly vascular, neuroglial tissue containing nerve-cells of moderate size.

THE MESENCEPHALON OR MID-BRAIN

The **mesencephalon** or **mid-brain** is derived from the second of the three primary cerebral vesicles. In the course of its development in man and in its phylogenetic history it retains a much simpler form than either the fore-brain or the hind-brain. In lower vertebrates the leading feature of the mid-brain is the development in its roof-plate or *tectum* of the higher visual, and, later, the higher auditory centres. In the mammalia, however, these centres shift forwards to the neopallium, and the importance of the tectum is correspondingly diminished.

The sulcus limitans develops, as in the hind-brain and the spinal cord, differentiating the basal and the alar laminæ. Representatives of the somatic efferent column are present in the form of the nuclei of the third and fourth cranial nerves, and the somatic afferent column is represented by the mesencephalic nucleus of the trigeminal nerve. In these respects, therefore, the mid-brain shows indications of a primitive metamerism and resembles the medulla oblongata and the tegmental portion of the pons.

With the development of the neopallium of the cerebrum the mid-brain becomes invaded by great tracts of fibres of cortical origin. Some of these

form the great new motor-pathway from the cortex, while others are destined to be relayed in the nuclei pontis and constitute cerebro-cerebellar connexions (p. 921). These fibre tracts group themselves on the ventral aspect of the mid-brain on each side of the median plane and cause a characteristic alteration in its appearance.

Position and surface form.—The mid-brain passes upwards and forwards through the gap in the tentorium cerebelli and connects the pons and cerebellum (rhombencephalon) with the subthalamic region (diencephalon) and the cerebral hemispheres (telencephalon). It is the shortest segment of the brain-stem, being not more than 2 cm. in length. On each side it is related to the hippocampal gyrus, which hides its lateral aspect from view when the inferior, or basal, aspect of the brain is examined.

The mid-brain consists of *ventral* and *dorsal portions*, separated from one another in its interior by the aqueduct of the mid-brain (cerebral aqueduct), which represents the lumen of the primitive neural tube. The ventral portion consists of the two *cerebral peduncles*, which are separated from each other in front by a deep notch but are continuous with each other behind, across the median plane.

The dorsal portion, or *tectum*, comprises the *corpora quadrigemina*, which consist of four rounded elevations symmetrically arranged in superior and inferior pairs.

The **cerebral peduncles** emerge from the upper surface of the pons, one on each side of the median plane, and, diverging as they pass upwards and forwards, disappear into the substance of the cerebral hemispheres. Curving round each peduncle, close to the upper surface of the pons, a thin white band, named the *tænia pontis*, is frequently seen ; it enters the cerebellum between the middle and the superior cerebellar peduncles. The depressed area between the diverging cerebral peduncles forms the posterior part of the *interpeduncular fossa* (p. 971), and consists of a layer of greyish substance, termed the *posterior perforated substance* (p. 963).

The ventral surface of each peduncle is crossed anteriorly, from the medial to the lateral side, by the superior cerebellar and posterior cerebral arteries, while, close to the point of disappearance of the peduncle into the cerebral hemisphere, the optic tract winds backwards around it. The medial surface of the peduncle is marked by a longitudinal furrow, termed the *medial sulcus*, from which the roots of the oculomotor nerve emerge (fig. 866). In its upper part it forms the lateral boundary of the interpeduncular fossa. The lateral surface of the peduncle is in relation with the gyrus hippocampi of the cerebral hemisphere and is crossed from behind forwards by the trochlear nerve (fig. 838). This surface is marked by a longitudinal furrow, termed the *lateral sulcus* ; the fibres of the lateral lemniscus come to the surface in this sulcus, and pass backwards and upwards. Some of them disappear under the inferior quadrigeminal body ; the remainder enter the inferior brachium.

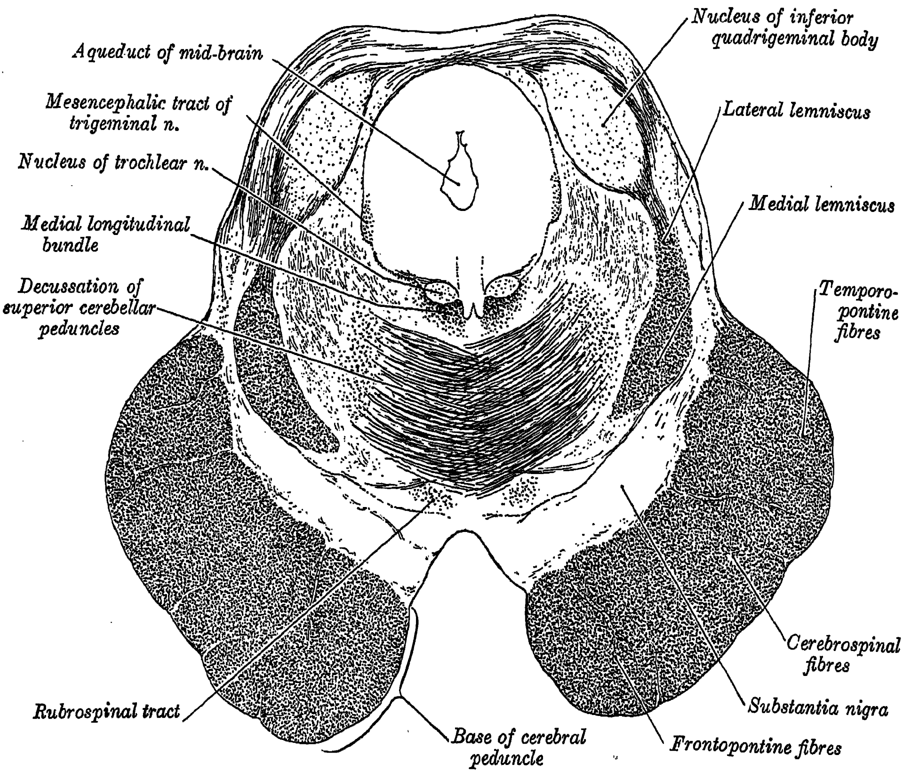
Structure of the cerebral peduncles (figs. 865, 866).—On transverse section, each peduncle is seen to consist of a dorsal and a ventral part, separated by a deeply pigmented lamina of grey matter, termed the *substantia nigra*. The dorsal part is named the *tegmentum* ; the ventral, the *base*. The basal parts of the peduncles are separated from each other, but the tegmenta are continuous with one another across the median raphe. Laterally, the tegmenta are free ; dorsally, they blend with the corpora quadrigemina.

The base is semilunar on transverse section, and consists almost entirely of longitudinal bundles of efferent fibres which arise from the cells of the cerebral cortex and are grouped into two principal sets, viz. cerebrospinal and cerebropontine (fig. 865). The *cerebrospinal* fibres are derived from the cells of the motor area of the cerebral cortex, and occupy the middle three-fifths of the base ; they descend through the pons and medulla oblongata, where some of them end in the nuclei of the motor cranial nerves of the opposite side, but most of them are continued into the pyramids of the medulla oblongata. The cerebropontine fibres arise in the cerebral cortex and terminate in the nuclei pontis, where they are relayed to the opposite cerebellar hemisphere. They are subdivided into two groups : (*a*) *frontopontine* and (*b*) *temporopontine*. (*a*) The frontopontine fibres arise in the frontal lobe, traverse the anterior limb

of the internal capsule, and occupy the medial one-fifth of the base of the cerebral peduncle. (*b*) The temporopontine fibres arise in the temporal lobe, traverse the posterior limb of the internal capsule and occupy the lateral one-fifth of the base of the cerebral peduncle; they originate in the temporal lobe and end in the nuclei of the pons.*

The **substantia nigra** is a layer of grey matter containing numerous, deeply pigmented, multipolar nerve-cells. It is semilunar on transverse section, its concavity being directed towards the tegmentum; from its convex surface, processes extend between the fibres of the base of the peduncle. Thicker medially than laterally, it reaches from the medial to the lateral sulcus, and extends from the upper surface of the pons to the subthalamic region; its medial part is traversed by the fibres of the oculomotor nerve as these stream

FIG. 865.—A transverse section through the mid-brain at the level of the inferior quadrigeminal bodies. (Semidiagrammatic. After Villiger.)



forwards to reach the oculomotor sulcus. The fibre connexions and the functions of the substantia nigra are still obscure. It has been stated that it receives afferent fibres from the inferior frontal gyrus (Monakow), the medial and lateral lemnisci, the superior quadrigeminal bodies and the fasciculus retroflexus (p. 963), and that it sends efferent fibres into the tegmentum to reach the globus pallidus of the lentiform nucleus, the red nucleus and the superior quadrigeminal bodies. It is relatively small in lower mammals, and contains no pigment. It has been suggested recently that the substantia nigra constitutes a co-ordinating centre for proprioceptive impulses.

* A band of fibres, named the *tractus peduncularis transversus*, is sometimes seen emerging from the optic tract on the lateral aspect of the cerebral peduncle; it passes round the ventral surface of the peduncle about midway between the pons and the optic tract, and disappears by entering the interpeduncular fossa behind and lateral to the corpus mamillare, where it terminates in a small nucleus. This band is a constant structure in many mammals, but is only present in about thirty per cent. of human brains. Since it undergoes atrophy after enucleation of the eyeballs, it may be considered as being associated with the visual pathway.

The tegmentum of the mid-brain presents appearances which differ according to the level of the section examined. Below it is directly continuous with the tegmentum of the upper part of the pons and contains the same fibre tracts.

A. In its *lower part*, i.e. on a level with the inferior quadrigeminal bodies, the grey matter is restricted to the immediate environs of the aqueduct of the mid-brain and to the scattered collections in the reticular formation (fig. 865).

The *nucleus of the trochlear (fourth cranial) nerve* lies in the ventral part of the central grey matter, close to the median plane. It occupies a position homologous with that occupied by the abducent and hypoglossal nerves at lower levels in the brain-stem, and it constitutes the representative of the somatic efferent column. Closely related throughout its extent to the medial longitudinal bundle, which lies on its ventral aspect, the nucleus extends through the lower half of the mid-brain, and its upper limit lies just below the lower limit of the oculomotor nucleus. Its *outgoing fibres* pass laterally and backwards round the central grey matter. Inclining downwards, they decussate with each other immediately below the inferior quadrigeminal bodies and emerge from the dorsal aspect of the superior medullary velum (fig. 864).

The unusual course of the outgoing fibres, their decussation and their emergence on the dorsal aspect of the brain-stem, are very difficult to explain. The fact that in the embryo the trochlear nucleus is at first separated from the oculomotor nucleus by a distinct gap and later migrates headwards into the mid-brain until it reaches the caudal end of the oculomotor nucleus, indicates that the region of the isthmus rhombencephali is unstable. Frazer has recently suggested that the isthmus is partly ‘ telescoped ’ into the mid-brain, and that during this process the basal lamina extends laterally over the inner surface of the alar lamina, carrying the point of emergence of the trochlear nerve with it. The same author suggests, on the analogy of the anterior nerve-roots of the spinal nerves, which possess a large homolateral and a small contralateral component, that the trochlear nerve possesses a large contralateral and a small homolateral component.*

The *mesencephalic nucleus of the trigeminal nerve* lies in the lateral part of the central grey matter. It is the representative of the somatic afferent column and retains its primitive position in the alar lamina. Fibres of the mandibular division run upwards on its lateral aspect and terminate within it (p. 1043). They are believed to convey proprioceptive fibres from the muscles of mastication.†

Apart from these two nuclei the central grey matter at this level contains large numbers of scattered nerve-cells, the significance of which is unknown. Irregular collections of grey matter occur in the reticular formation, especially in the region immediately above the pons.

The *white matter* at this level of the mid-brain contains all the tracts which have already been examined in the tegmentum of the pons, and it is characterised by the great decussation of the fibres of the superior cerebellar peduncles.

The *superior cerebellar peduncle*, which has already been described (p. 931), enters the dorsilateral part of the tegmentum and passes forwards and medially round the central grey matter to reach the median raphe, where it decussates with its fellow of the opposite side. Having crossed the median plane, the

* See footnote on p. 114.
In all vertebrates the trochlear nerves behave in the same peculiar way. Nevertheless it would appear to be certain that in some unknown ancestral form the trochlear nerves, like the oculomotor, abducent and hypoglossal nerves, emerged from the ventrilateral aspect of the brain-stem. It has been suggested that the trochlear nerve originally supplied the muscles of the pineal eye, and this would offer an explanation for the course of the fibres in a dorsal direction. The position of the nerve within the mid-brain medial to the mesencephalic nucleus of the trigeminal nerve may possibly be associated with the history of the nucleus, which is generally regarded as a derivative of the neural crest, secondarily included in the substance of the brain-stem. If, prior to the inclusion of the nucleus, the trochlear nerve passed dorsally across the side of the brain-stem to reach the muscles of the pineal eye, it too would necessarily be included in the process. The decussation of the trochlear nerves presents a further difficulty, but it might possibly be ascribed to changes affecting the disposition of the muscles of the primitive pineal eye. It must be admitted, however, that these explanations are in the highest degree speculative.

† In connexion with the function of this nucleus see also papers by E. P. Stibbe, *Journal of Anatomy*, vol. lxiv. 1929, and vol. lxv. 1903, and H. H. Woollard, *Journal of Anatomy*, vol. lxv. 1931.

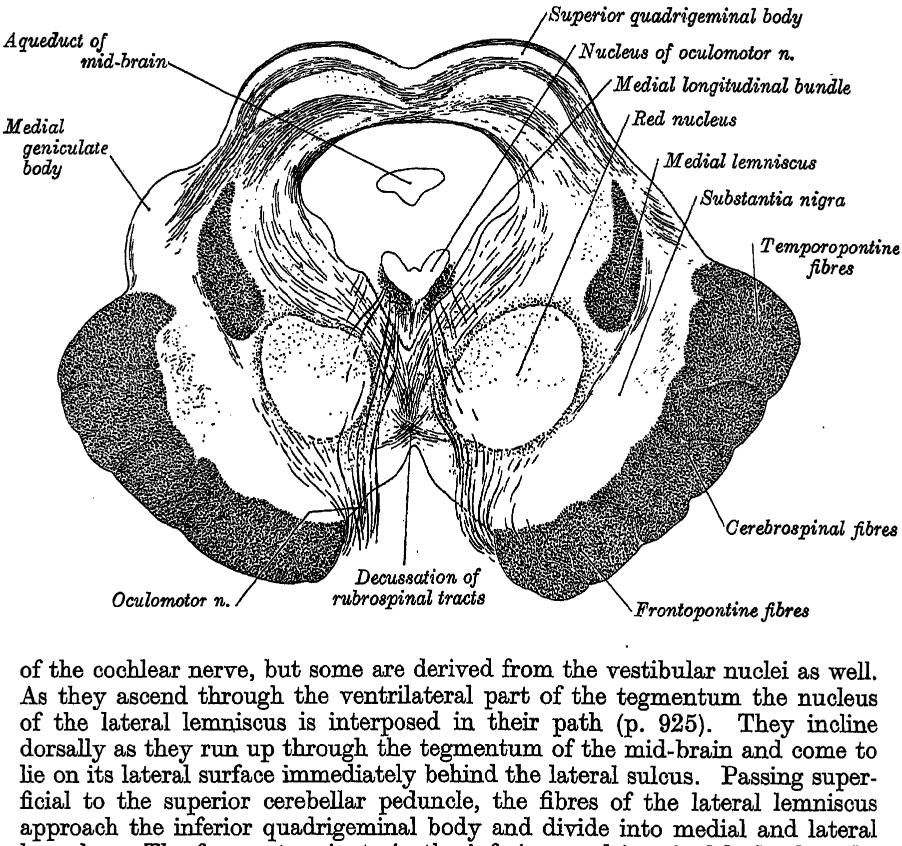
fibres divide into ascending and descending branches, and the former terminate for the most part in the red nucleus, which they encapsulate, but some are continued upwards and have been variously described as ending in the nucleus subthalamicus, the medial and the lateral nuclei of the thalamus.

The *medial longitudinal fasciculus* retains its intimate relationship to the somatic efferent column, and therefore lies dorsal to the decussating fibres of the superior cerebellar peduncles.

The *medial lemniscus* forms a curved band lying dorsal to the lateral part of the substantia nigra, in which some of its fibres terminate. Laterally the tract is closely related to the lateral lemniscus, which is ascending with a backward inclination to reach the inferior quadrigeminal body.

The *lateral lemniscus* is formed in the tegmentum of the pons by the fibres issuing from the corpus trapezoideum and by the fibres of the auditory striæ. These arise, for the most part, in the ventral and dorsal nuclei, respectively,

Fig. 866.—A transverse section through the mid-brain at the level of the superior quadrigeminal bodies. (Semidiagrammatic. After Villiger.)



of the cochlear nerve, but some are derived from the vestibular nuclei as well. As they ascend through the ventrilateral part of the tegmentum the nucleus of the lateral lemniscus is interposed in their path (p. 925). They incline dorsally as they run up through the tegmentum of the mid-brain and come to lie on its lateral surface immediately behind the lateral sulcus. Passing superficial to the superior cerebellar peduncle, the fibres of the lateral lemniscus approach the inferior quadrigeminal body and divide into medial and lateral branches. The former terminate in the inferior quadrigeminal body, but the latter are continued into the inferior brachium by which they are conducted to the medial geniculate body.

The fibres of the *spinal* and *trigeminal lemnisci* are indistinguishable from the fibres of the lateral portion of the medial lemniscus, with which they ascend to the thalamus.

B. In its *upper part* the tegmentum presents the same general plan, but it is strikingly modified by the appearance of a large nucleus, which extends upwards into the subthalamic region and is termed the red nucleus.

The *central grey matter* surrounds the aqueduct and contains in its ventrimedial portion the *nucleus of the oculomotor nerve,* which represents the somatic efferent column. This nucleus is closely related on its ventrilateral aspect to

the medial longitudinal bundle, and inferiorly it extends to the upper end of the trochlear nucleus (fig. 865).

The cell-groups are arranged in such a definite manner that it is possible to subdivide the nucleus into a number of constituent parts, viz. (*a*) The dorsilateral nucleus ; (*b*) the ventrimedial nucleus ; (*c*) the central nucleus ; (*d*) the Edinger-Westphal nucleus ; and (*e*) the caudal central nucleus (fig. 937). The dorsilateral nucleus does not extend so far inferiorly as the ventrimedial, which is in direct line with the trochlear nucleus. The central nucleus stretches across the median plane and is common to both oculomotor nerves. These three nuclei contain typical large pyramidal motor cells, and endeavours have been made to determine a localisation of function in them. The available evidence suggests that the dorsilateral nucleus is associated with upward movements of the eye, and the ventrimedial with downward movements. The close relationship of the latter to the trochlear nucleus, which is also concerned with downward movements, is in keeping with this scheme of localisation. The central nucleus, according to Brouwer and other workers, is concerned with movements of convergence (see also p. 1040). The Edinger-Westphal nucleus differs from these three nuclei in the smaller size of its constituent cells. It is situated more dorsally in the central grey matter and extends headwards beyond the other nuclei but does not reach so far inferiorly. This nucleus has been regarded for many years as the site of origin of those fibres of the third nerve which innervate the ciliary muscle and, according to some authorities, the sphincter iridis. Although present in most mammals, it is not constant, and according to Latumeten, it gives no direct fibres to the ciliary ganglion.

The *nucleus of Darkschewitsch* is a large-celled nucleus which lies dorsilateral to the upper end of the oculomotor nucleus in the central grey matter. It sends efferent fibres into the medial longitudinal bundle and also into the posterior commissure, but its functional significance is unknown.

The **red nucleus** is a large, ovoid mass of grey matter which occupies most of the medial part of the tegmentum of the upper half of the mid-brain, and extends upwards into the subthalamic region. Ventrally it is related to the substantia nigra, from which it is only separated by some of its surrounding fibres. Laterally it is related to the medial lemniscus ; dorsally it is separated from the central grey matter by the formatio reticularis, here very much reduced in area, and the medial longitudinal bundle. On its medial side, its surrounding fibres and the outgoing oculomotor nerve separate the nucleus from the median raphe and the ventral and dorsal tegmental decussation.

It is not homogeneous in structure, and the cells of the upper two-thirds, which are small in size, bear no resemblance to the large cells which are found in its lower third.

Afferent fibres reach the red nucleus from the superior cerebellar peduncle, and the globus pallidus of the lentiform nucleus (striatorubral fibres), and, possibly, direct from the cerebral cortex. The origin of the cortical fibres has been variously ascribed to the frontal, temporal and parietal lobes.

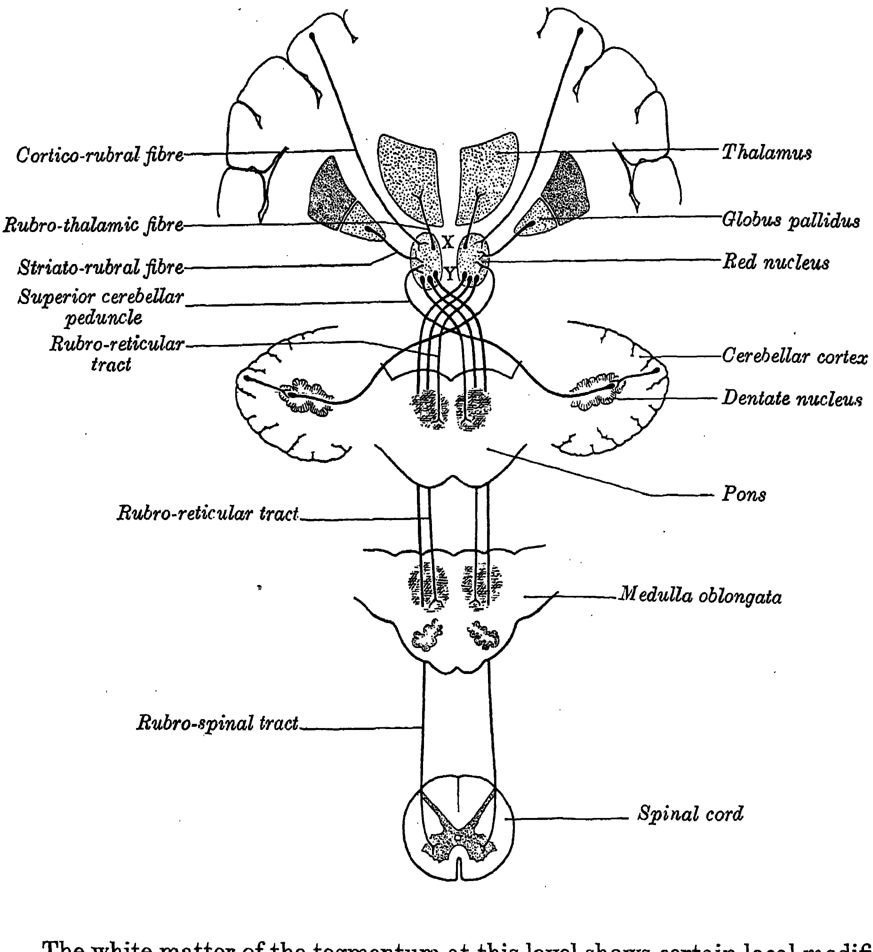
The efferent fibres from the red nucleus connect it with (1) the anterior column of the grey matter of the spinal cord (rubrospinal tract), (2) the nuclei of the reticular formation of the pons and the medulla oblongata (rubroreticular tract) and (3) the thalamus.

The red nucleus constitutes an important cell-station on the principal efferent pathway from the cerebellum to the spinal cord. At the same time it is also interposed on the pathway from the corpus striatum to the spinal cord. It is clear from both these connexions that the red nucleus plays an important part in the nervous mechanism of movements. It is connected to the anterior column of the grey matter of the spinal cord by the rubrospinal tract, but it is not at all certain that this is the principal pathway involved, for although the rubrospinal tract is a large bundle in many lower mammals, it is relatively small in man. It is possible that the rubroreticular tract, which is relatively large in man, may transmit impulses from the cerebellum and also, perhaps, from the corpus striatum, through a series of relay stations in the reticular formation in the hind-brain to the spinal cord. Rademaker, as the result of a long series of experiments, believes that the red nucleus acts as a centre for the distribution

of muscle tonus and that an intact red nucleus is an essential part of the arc concerned in the labyrinth-righting and body-righting reflexes.

Although it is clear that the large-celled lower portion of the red nucleus is derived from the basal lamina of the mid-brain, it would appear that the small-celled upper portion is a derivative of the diencephalon. This part of the nucleus becomes developed and elaborated *pari passu* with the expansion of the cerebellar hemispheres and the frontal lobes of the cerebrum, with which, according to Monakow, the red nucleus is freely connected.

FIG. 867.—A scheme to show the connexions of the red nucleus.



The white matter of the tegmentum at this level shows certain local modifications, chiefly in the region of the median raphe.

The *rubrospinal tract* takes origin at this level from the large cells in the lower part of the red nucleus. The fibres at once pass to the median raphe and there decussate in its ventral portion with the corresponding fibres of the opposite side, forming the *decussation of the rubrospinal tracts* (ventral tegmental decussation). They then pass downwards in front of the decussation of the superior cerebellar peduncles and descend in the formatio reticularis of the pons and medulla oblongata. Finally they enter the spinal cord, lying on the ventrilateral aspect of the lateral cerebrospinal tract, and terminate by arborising round the cells in the anterior column of the grey matter. Despite the fact that the rubrospinal tract is a relatively small bundle in man, it is generally regarded as the principal pathway connecting the corpus striatum and the cerebellum with the spinal cord.

The *tectospinal* and the *tectobulbar tracts* also take origin at this level. Their fibres arise in the grey matter of the superior quadrigeminal bodies and sweep

forwards round the central grey matter to decussate with one another in the median raphe ventral to the oculomotor nucleus and the medial longitudinal bundle. Emerging from the decussation the tectospinal tract descends on the ventral aspect of the medial longitudinal bundle as far as the decussation of the medial lemniscus in the medulla oblongata. Thereafter it diverges ventrilaterally and in the spinal cord it lies in the lateral column in front of the rubrospinal tract.* The tectobulbar tract, which may be divided into a dorsal, crossed tract and a ventral, uncrossed tract, descends through the reticular formation of the mid-brain and the pons and terminates by sending its fibres into the oculomotor, trochlear, abducent and accessory nuclei. It serves as a pathway for reflex movements of the eyes in response to visual stimuli.

The *medial longitudinal bundle* lies on the ventrilateral aspect of the oculomotor nucleus. At this level its fibres are more spread out than they are at lower levels in the brain-stem, but the intimate relationship to the somatic efferent nuclei is retained.

The bundle extends upwards to the *interstitial nucleus*—a small collection of cells situated in the lateral wall of the third ventricle immediately above the upper end of the aqueduct of the mid-brain—which contributes fibres to it. As has already been seen, the medial longitudinal bundle retains its position relative to the central grey matter throughout the whole extent of the mid-brain, pons and the upper part of the medulla oblongata. It is displaced forwards by the successive decussations of the medial lemnisci and the pyramidal tracts, and becomes continuous with the anterior intersegmental fasciculus of the spinal cord.

The intimate relationship which it bears successively to the nuclei of the third, fourth and sixth cranial nerves, to the emerging fibres of the seventh, the auditory striæ of the eighth and the nucleus of the twelfth nerve renders it a very convenient pathway for the passage of fibres from one nucleus to another in the brain-stem. The harmonious co-operation obviously existing between the facial nerves and the hypoglossal nerves in the movements of the lips and tongue in speech is frequently attributed to connexions between their nuclei conveyed by the medial longitudinal bundle, and a similar explanation is given for the co-operation of the oculomotor, trochlear and abducent nerves in the movements of the eyes. It is, however, very doubtful whether it is the medial longitudinal bundle which provides the pathway for these connexions. Edinger, Winkler and others have shown that the most substantial contributions to the bundle are made by the vestibular nuclei, and their work strongly suggests that its chief function is to ensure the co-ordinate movements of the eyes and head in response to stimulation of the eighth nerve. Fibres from the vestibular nuclei (superior, lateral and medial), both of the same and of the opposite side, join the bundle, where they ascend, descend or divide into ascending and descending branches. These vestibular fibres send collaterals to, or they may end in, the nuclei of the third, fourth and sixth cranial nerves and the spinal nucleus of the eleventh nerve. In addition, fibres join the bundle from the dorsal nucleus of the corpus trapezoideum and the nucleus of the lateral lemniscus. It is probable, therefore, that the cochlear as well as the vestibular nerve is capable of influencing the movements of the eyes and head through the bundle. The continuity of the bundle with the anterior intersegmental tract offers a pathway to those nuclei of the spinal cord which innervate the rotator muscles of the head and neck other than the sternomastoid.

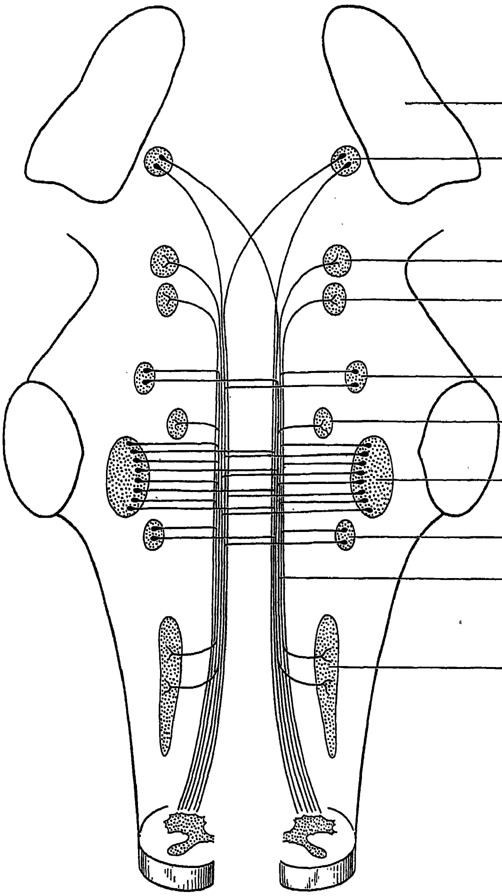
The *inferior brachium* forms a rounded strand on the lateral aspect of the upper part of the mid-brain. Its fibres are derived from the lateral lemniscus and they are ascending to reach the medial geniculate body. In their course they separate the dorsilateral fibres of the medial lemniscus from the surface.

The **corpora quadrigemina** (fig. 864) are four rounded eminences which form the dorsal part of the mesencephalon. They are situated above and in front of the superior medullary velum, and below and behind the third ventricle and posterior commissure. They lie below the splenium of the corpus callosum, and are partly overlapped on each side by the pulvinar of the thalamus. The corpora quadrigemina are arranged in pairs (superior and inferior), and are separated from one another by a cruciform sulcus. The longitudinal part

* See footnotes * on pp. 899 and 900.

of this sulcus expands superiorly to form a slight depression in which the *pineal body* (p. 961) lies. From the inferior end of the longitudinal sulcus a white ridge, termed the *frenulum veli*, is prolonged downwards to the superior medullary velum; at the sides of this ridge the trochlear nerves emerge, and pass forwards on the lateral aspects of the cerebral peduncles to reach the base of the brain. The *superior corpora quadrigemina* are larger and darker in colour than the inferior, and constitute centres for visual reflexes (p. 968). The *inferior corpora quadrigemina*, though smaller, are somewhat more prominent than the superior and are associated with the auditory pathway (p. 951).

FIG. 868.—A scheme of the connexions of the medial longitudinal bundle.

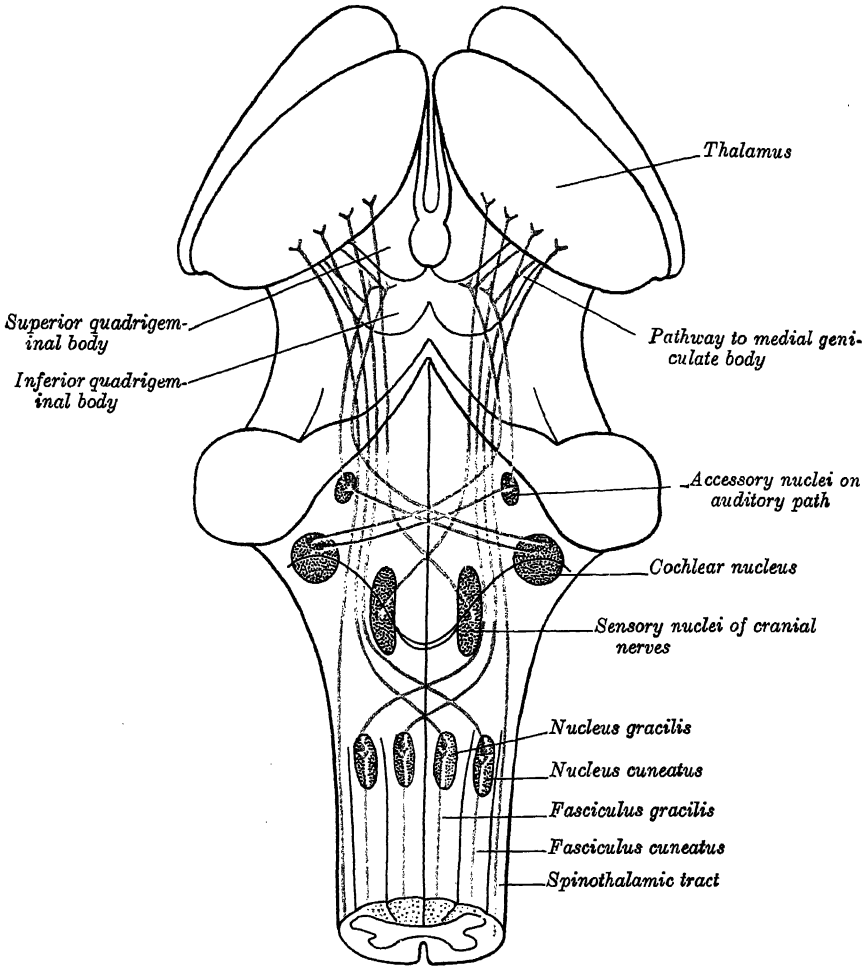


From the lateral aspect of each quadrigeminal body a white band, termed the *brachium*, is prolonged upwards and forwards. The *superior brachium* extends laterally from the superior quadrigeminal body, and, passing between the pulvinar and medial geniculate body, is partly continued into an eminence called the lateral geniculate body, and partly into the optic tract. It conducts visual fibres from the optic radiation to the superior quadrigeminal body. The *inferior brachium* passes forwards and upwards from the inferior quadrigeminal body; it conveys fibres from the lateral lemniscus and, possibly, also from the inferior quadrigeminal body to the medial geniculate body and, in addition, fibres from the inferior quadrigeminal body to the thalamus.

Structure of the corpora quadrigemina.—The *inferior quadrigeminal body* consists of a compact nucleus of grey matter which contains large and small multipolar nerve-cells, and is more or less completely surrounded by fibres derived from the lateral lemniscus; most of these fibres end in the grey nucleus of the same side, but some cross to that of the opposite side. These, however,

do not account for all the fibres of the lateral lemniscus, for the majority are continued through the inferior brachium to the medial geniculate body, where they are relayed to the auditory cortex (p. 995). The inferior quadrigeminal body also receives afferent fibres from the temporal cortex, and, of its efferent fibres, some pass into the inferior brachium and are destined for the thalamus and, possibly, the medial geniculate body, while others descend into the tegmentum to reach the motor nuclei of the cranial nerves.

FIG. 869.—A scheme showing the course of the fibres of the lemnisci; lateral lemniscus in *red*, medial and spinal lemnisci in *blue*.



The inferior quadrigeminal body reaches its highest development in mammals, and it is only found in those animals which possess a well-developed cochlea. It is to be regarded as a centre for auditory and, possibly, some vestibular reflexes (p. 922) rather than as a relay station on the path to the cerebral cortex. In this connexion it should be observed that many of the fibres of the lateral lemniscus divide into medial and lateral branches which are distributed to the inferior quadrigeminal body and the medial geniculate body, respectively.

The *superior quadrigeminal body* is covered by a thin stratum of white fibres, which constitute the *stratum zonale*. Beneath this the *stratum cinereum* forms a cap-like layer of grey matter, thicker in the centre than at the circumference, and consisting of numerous small multipolar nerve-cells imbedded in a fine network of nerve-fibres. Still deeper is the *stratum opticum*, containing

large multipolar nerve-cells separated by numerous fine nerve-fibres. Finally, there is the *stratum lemnisci*, consisting of fibres, many of which are derived from the medial lemniscus ; others are commissural and derived from the cells of the stratum opticum ; many large multipolar nerve-cells are interspersed among these fibres.

Afferent fibres reach the superior quadrigeminal body from at least three sources : (1) fibres originating in the retina * and conveyed by the superior brachium ; (2) fibres arising in the visual cortex of the occipital lobe and travelling by the optic radiation to the superior brachium ; (3) fibres arising in the spinal cord and ascending in the spinotectal tract.

Efferent fibres take part in the dorsal tegmental decussation and constitute the tectobulbar and the tectospinal tracts (p. 948), which establish connexions with the motor nuclei of the cranial nerves, more particularly the third, fourth, sixth and eleventh, and the anterior column cells of the spinal cord. Others cross the median plane to reach the superior quadrigeminal body of the opposite side, while still others have been described as entering the medial longitudinal fasciculus.

In fishes, reptiles and birds the whole of the tectum is given over to the superior corpora quadrigemina, which thus constitute the corpora bigemina and are frequently termed the optic lobes. In these animals they function as one of the highest visual centres and they receive practically all the fibres from the retinæ. In mammals, however, the evolution of the visual cortex has resulted in a diminution of the importance of these centres, and most of the fibres of the optic tracts avoid them and are relayed in the lateral geniculate bodies on their way to the higher centres. The superior quadrigeminal body continues to receive some fibres from the optic tract,* and it is believed that they are an essential part of the arc of the light reflex. In addition the superior quadrigeminal body receives afferent fibres from the visual cortex, which are relayed through the tectobulbar and tectospinal tracts, so as to provide a pathway for reflex movements of the musculature of the eyes, head and neck which may be necessitated by visual impressions.

The **aqueduct of the mid-brain** (cerebral aqueduct) is a narrow canal, about 15 mm. long, situated between the corpora quadrigemina and tegmentum, and connecting the third with the fourth ventricle. Its form, as seen in transverse sections, varies at different levels, being T-shaped below, triangular above, and oval in the middle ; its central part is slightly dilated, and was named by Retzius the *ventricle of the mid-brain*. It is lined with ciliated columnar epithelium, and is surrounded by a layer of grey matter named the *central grey stratum* ; this is continuous below with the grey matter in the floor of the fourth ventricle, and above with that of the third ventricle. Dorsally the aqueduct is partly separated from the grey matter of the quadrigeminal bodies by the fibres of the lemnisci ; ventral to it are the medial longitudinal bundle, and the formatio reticularis of the tegmentum. Scattered throughout the central grey stratum are numerous nerve-cells of various sizes, interlaced by a network of fine fibres. Besides these scattered cells it contains three groups, which constitute the nucleus of the mesencephalic root of the trigeminal nerve and the nuclei of the oculomotor and trochlear nerves (pp. 945 and 946).

THE FORE-BRAIN OR PROSENCEPHALON

The **fore-brain or prosencephalon** consists of : (1) the *diencephalon*, corresponding in a large measure to the third ventricle and the structures which bound it ; and (2) the *telencephalon*, comprising the largest part of the brain, viz. the cerebral hemispheres ; these hemispheres are connected with each other across the median plane, and each contains an extensive cavity, named the lateral ventricle. The lateral ventricles communicate with each other and with the third ventricle through the interventricular foramen, and are separated

* Some authorities deny that any fibres originating in the retina terminate in the superior colliculi.

from each other over a wide area only by a median septum, termed the septum lucidum ; this contains a slit-like cavity, which does not communicate with the ventricles.

The Diencephalon

The **diencephalon** is derived from the caudal end of the fore-brain. In the human embryo and in all vertebrates it is situated in front of (headwards of) the anterior (or upper) end of the notochord, and it may therefore be regarded as an extension of the brain beyond the limits of the primitive segments of the body. It may be expected that the imprints of metamerism and branchiomerism, which have been observed in the brain-stem and spinal cord, will no longer be found in the diencephalon.

The recent work of Kingsbury and J. B. Johnston suggests that the sulcus limitans does not extend into the region of the fore-brain, which is derived in its entirety from the alar laminæ.

The lateral walls of this portion of the embryonic neural tube undergo enormous thickening and form two large nuclear masses, which are termed the *thalami*. They are the largest and most important of all the derivatives of the diencephalon. In primitive vertebrates they constitute the highest centres for the correlation of all sensory impressions but, with the evolution of the neopallium, they become relegated to a position of less importance, acting as relay stations on the sensory pathway to the cortex. Although they are no longer the dominant factor in determining behaviour they do retain a large measure of their earlier importance, for it would appear that sensory impressions can reach consciousness in the thalami themselves, when their cortical connexions have been severed.

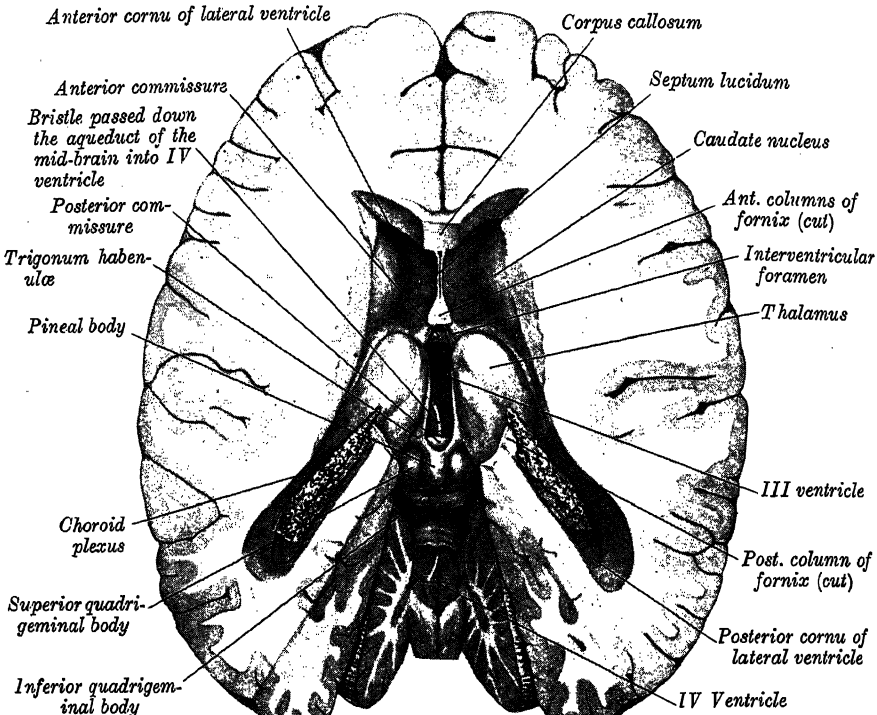
Caudal to the thalamus two elevations appear on the lateral aspect of the diencephalon, and they can at first be recognised on the inner wall as two hollowed out areas. They form the medial and lateral geniculate bodies, which together constitute the *metathalamus*. As the thalamus enlarges it extends tailwards and, growing backwards so as to overhang the mid-brain, intervenes between the geniculate bodies and the cavity of the diencephalon. The medial geniculate body has already been seen in the groove between the lateral aspect of the mid-brain and the overhanging posterior end of the thalamus, while the lateral geniculate body comes to lie in close contact with the inferior aspect of the posterolateral part of the thalamus and appears to be incorporated in it.

The roof-plate of the fore-brain retains its epithelial character throughout the greater part of its extent and forms, in the adult, the *ependymal roof of the third ventricle*. At its posterior (or caudal) end the roof and the adjoining portions of the lateral walls give rise to a number of structures which together constitute the *epithalamus*. A collection of cells in this part of the lateral wall forms the *habenular nucleus* (habenular ganglion), which sends its fibres across the median plane through the roof-plate, to constitute the *habenular commissure*. More caudally a second commissural bundle invades the roof, and is termed the *posterior commissure*. In the interval between these two commissures a hollow diverticulum grows backwards in the median plane. This is termed the *epiphysis*. In many reptiles it gives off a second process from the anterior wall of its base, which constitutes the pineal or parietal eye (p. 962). This organ has been identified in the human embryo, but it does not persist ; the epiphysis, on the other hand, which forms a hollow glandular structure in reptiles, secreting directly into the third ventricle, becomes converted into a solid organ, termed the *pineal body*.

We have seen how the thalamus, the metathalamus, the epithalamus and a large part of the roof of the third ventricle are derived from the diencephalon. The parts which have still to be considered are derived from the ventral portions of the lateral walls and from the floor. They contribute to the formation of the *hypothalamus*, forming the subthalamic region, the corpora mamillaria, the tuber cinereum, and the infundibulum. The remainder of the hypothalamus is derived from the telencephalon and includes the optic chiasma and the lamina terminalis.

The *subthalamic region* is the upward continuation of the tegmentum. It lies immediately below the thalamus in the human brain and contains certain masses of grey matter derived from the alar laminæ. The mamillary bodies form as a median thickening in the floor of the diencephalon, which is subsequently divided into two by a median groove. They form an important cell-station on the efferent pathway from the rhinencephalon (p. 987). The area in front of them constitutes the tuber cinereum. This area is very highly developed in those fishes in which the olfactory is dominated by the gustatory sense, but it undergoes marked reduction in air-breathing vertebrates.

FIG. 870.—The ventricles of the brain. Exposed from above and behind.



The splenium and most of the trunk of the corpus callosum have been removed; and the body of the fornix and most of the tela chorioidea have been excised, together with portions of the occipital lobes and the cerebellum. A bristle has been passed from the third ventricle through the aqueduct of the mid-brain into the fourth ventricle.

The *infundibular process* arises as a hollow outgrowth from the floor of the diencephalon, which subsequently loses its cavity and becomes converted into a solid mass of cells to form the posterior lobe of the hypophysis cerebri. The stalk which connects the hypophysis to the floor of the third ventricle forms the infundibulum, and it retains its hollow character in the adult. It will be remembered that the anterior lobe of the hypophysis develops as a hollow diverticulum from the roof of the primitive mouth (p. 166), and it is probable that in some ancestral vertebrates there was a bucconeural duct, such as occurs in larval ammocetes. Such a duct provided for the passage of water from the mouth to the neural tube and afforded the possibility of a water-vascular circulation for the central nervous system. In all reptiles and amphibia the infundibular process remains hollow, but in nearly all mammals it becomes a solid body and forms, as in man, the posterior lobe of the hypophysis cerebri.

The *optic chiasma* is developed in association with the optic nerves. Before the fore-brain is differentiated into the telencephalon and the diencephalon, two diverticula grow out from its inferolateral aspects to form the optic vesicles. The connexion of the vesicle with the fore-brain lengthens into an optic stalk, which retains its original hollow character for some time. Nerve fibres from

the retina grow in along the walls of the stalk, and as a result its cavity becomes obliterated and is replaced by a solid optic nerve. The optic recess of the third ventricle is all that remains of the cavity of the stalk. In all vertebrates the fibres of the optic nerves decussate, either completely or partially, in the floor of the fore-brain, and constitute the optic chiasma (p. 967).

The *lamina terminalis* is the cephalic end of the neural tube and, in view of the development of the roof and floor of this part of the telencephalon, it forms the one area where large and important commissural connexions between the cerebral hemispheres are able to develop.

Parts derived from the diencephalon.—The diencephalon comprises the thalamus, metathalamus and epithalamus (which together constitute the *thalamencephalon*), and most of the hypothalamus, but these structures include so many of the boundaries of the third ventricle of the brain that it will be convenient to describe the anterior part of the hypothalamus and the third ventricle as a whole in this section, together with the true derivatives of the diencephalon.

The thalami (figs. 871, 872) are two large ovoid masses, situated one on each side of the third ventricle and reaching for some distance behind that cavity. Each thalamus is about 4 cm. long, and has two ends and four surfaces.

The *anterior end* is narrow; it lies close to the median plane and forms the posterior boundary of the interventricular foramen.

The expanded *posterior end*, which is termed the *pulvinar*, is directed backwards and laterally and overhangs the superior quadrigeminal body and the superior brachium. The lateral geniculate body (p. 960) forms a small, oval elevation on the inferior aspect of its lateral part. Inferiorly the pulvinar is separated from the medial geniculate body (p. 959) by the superior brachium.

The *superior surface* is free, slightly convex, and covered by a layer of white matter, termed the *stratum zonale*. It is separated laterally from the ventricular surface of the caudate nucleus by a white band, termed the *stria semicircularis* (stria terminalis), and by the thalamostriate vein (vena terminalis) (p. 814). It is divided into a medial and a lateral portion by an oblique shallow furrow, which runs from behind forwards and medially from the lateral part of the posterior end to the anterior part of the medial border; this furrow corresponds with the lateral margin of the fornix. The lateral part forms a portion of the floor of the lateral ventricle. It is covered with the epithelium of that cavity, and is partly hidden by the vascular fringe of the choroid plexus of the lateral ventricle (fig. 872). The medial part of this surface is covered with the tela chorioidea of the third ventricle, by which it is separated from the body of the fornix. Between the lateral edge of the fornix and the upper surface of the thalamus the lateral margin of the tela chorioidea with its contained plexus is invaginated into the ventricle through the choroidal fissure. In front, the superior surface is separated from the medial surface by a narrow, raised ridge from which the epithelial lining of the third ventricle is reflected to the under surface of the tela chorioidea. This ridge covers a small bundle of white fibres, named the stria habenularis (p. 961). Posteriorly it turns medially to form the anterior boundary of the *trigonum habenulæ* (fig. 871), from which the upper surface of the thalamus is separated by the *sulcus habenulæ*.

The *inferior surface* rests upon and is continuous with the upward prolongation of the tegmentum (*subthalamic tegmental region*).

The *medial surface* constitutes the upper part of the lateral wall of the third ventricle; it is covered with a thin layer of grey matter, and is connected to the corresponding surface of the opposite thalamus by a flattened grey band, named the *connexus interthalamicus* (massa intermedia). This band lies close behind the interventricular foramen, and averages about 1 cm. in its anteroposterior diameter: it sometimes consists of two or even three parts, and occasionally is absent. It contains nerve-cells and nerve-fibres; a few of the latter may cross the median plane, but most of them pass towards the median plane and then curve laterally on the same side.

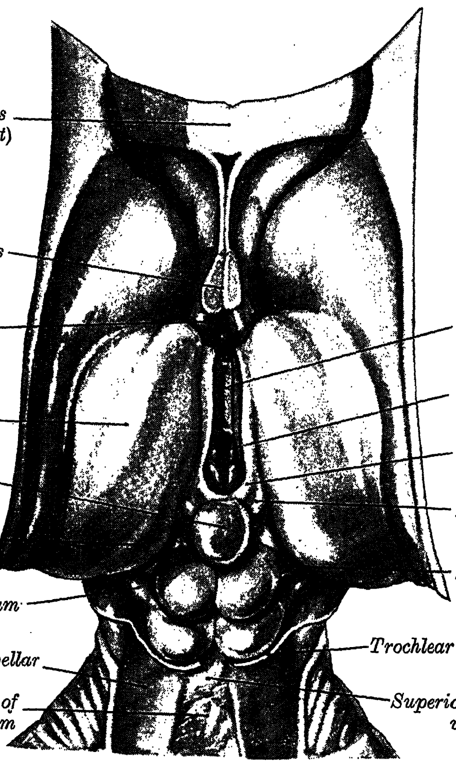
On its *lateral surface* there is a thick band of white substance consisting of itinerant fibres (projection fibres) which form the posterior limb of the internal capsule and separate the thalamus from the lentiform nucleus of the corpus striatum (fig. 872).

Structure.—The thalamus consists chiefly of grey matter, but its upper

surface is covered by a layer of white matter, named the *stratum zonale*, and its lateral surface by a similar layer, termed the *external medullary lamina*. Its grey matter is incompletely subdivided into three parts—anterior, medial, and lateral—by a vertical white layer, the *internal medullary lamina* (fig. 873).

The *anterior nucleus* comprises the anterior tubercle, and its tapered posterior end intervenes between the medial and lateral nuclei. The *medial nucleus* lies between the internal medullary lamina on the lateral side and the third ventricle on its medial side. These two nuclei are phylogenetically the oldest portion of the thalamus and together comprise the *palæothalamus*. They have, however, become modified in structure and progressively differentiated in the process of evolution, and it must not be assumed that their functions have

FIG. 871.—The thalami exposed from above by removal of the trunk and splenium of the corpus callosum, the body of the fornix, and the tela chorioidea.



The trunk and splenium of the corpus callosum, most of the septum lucidum, the body of the fornix, the tela chorioidea with its contained plexuses and the epithelial roof of the third ventricle have all been removed.

remained entirely primitive. The *lateral nucleus* lies between the internal and the external medullary laminæ. It is the largest of the three nuclei, forming the greater part of the thalamus and constituting the *neothalamus*. It includes the *pulvinar* and is traversed by numerous fibres which pass through the internal capsule to reach the cerebral cortex.

Connexions * (fig. 874).—In man the thalamus is a large cell-station interposed on the sensory path to the cortex and short-circuiting a number of different impulses to the corpus striatum. It receives *afferents* from : (1) the medial lemniscus (proprioceptive and discriminative or gnostic sensibility) ; (2) the spinal lemniscus (pain and temperature) ; (3) the trigeminal lemniscus (all varieties of sensibility from the trigeminal area) ; (4) the mamillo-thalamic tract ; (5) the hypothalamus (visceral sensibility) ; (6) the superior cerebellar peduncle of the opposite side ; (7) the rubro-thalamic tract of the same side ; and (8) all parts of the cerebral cortex.

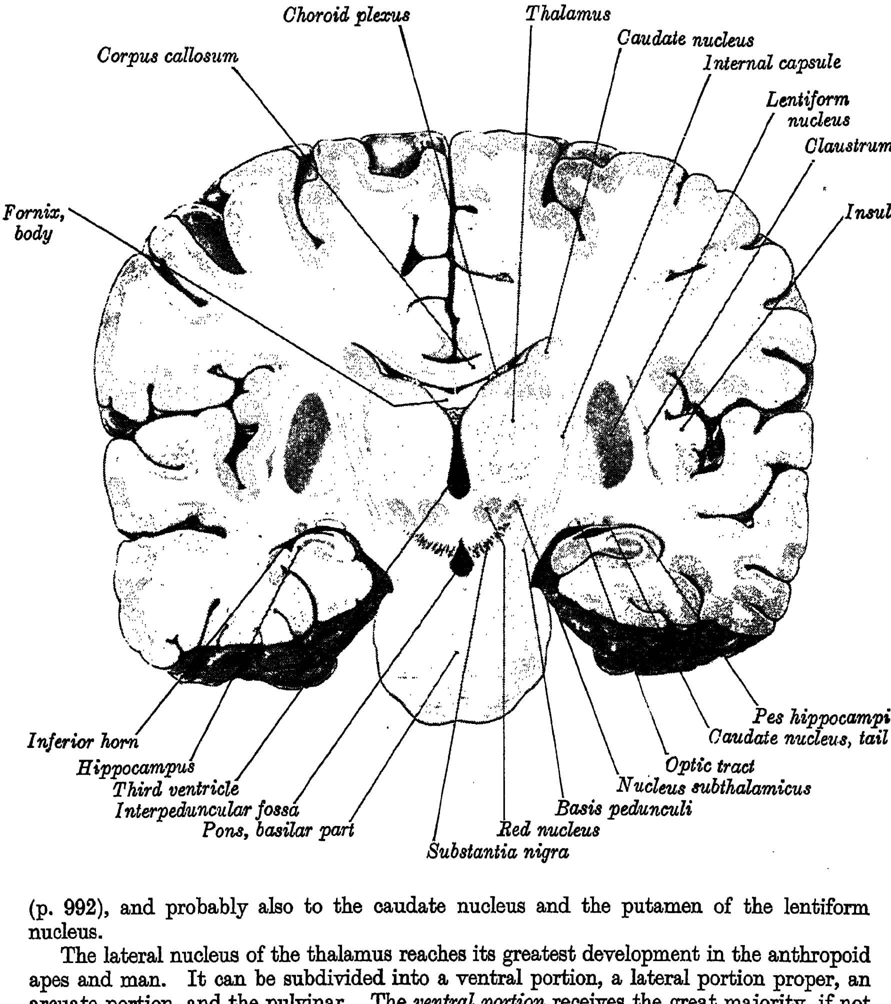
* The description in the text differs in many particulars from that given in previous editions and is based on the work of W. E. le Gros Clark, *Journal of Anatomy*, vols. lxvii., lxx. and lxxi., and *Brain*, vol. lv. etc.

Its *efferents* proceed through the internal capsule to reach: (1) all parts of the cerebral cortex, but especially the postcentral gyrus and the parietal and frontal association areas; (2) the caudate nucleus; and (3) the putamen of the lentiform nucleus.

Afferent stimuli reach the anterior nucleus through the mamillo-thalamic tract, and it therefore receives olfactory stimuli which have already been passed through the rhinencephalon. Its efferent fibres pass to the gyrus cinguli, to the medial nucleus of the thalamus and to the caudate nucleus.

The medial nucleus receives afferent fibres from the anterior nucleus and from certain of the nuclei of the hypothalmus. Its efferents pass to the frontal area of the cortex

FIG. 872.—A coronal section through the brain at the anterior part of the pons. Posterior aspect.



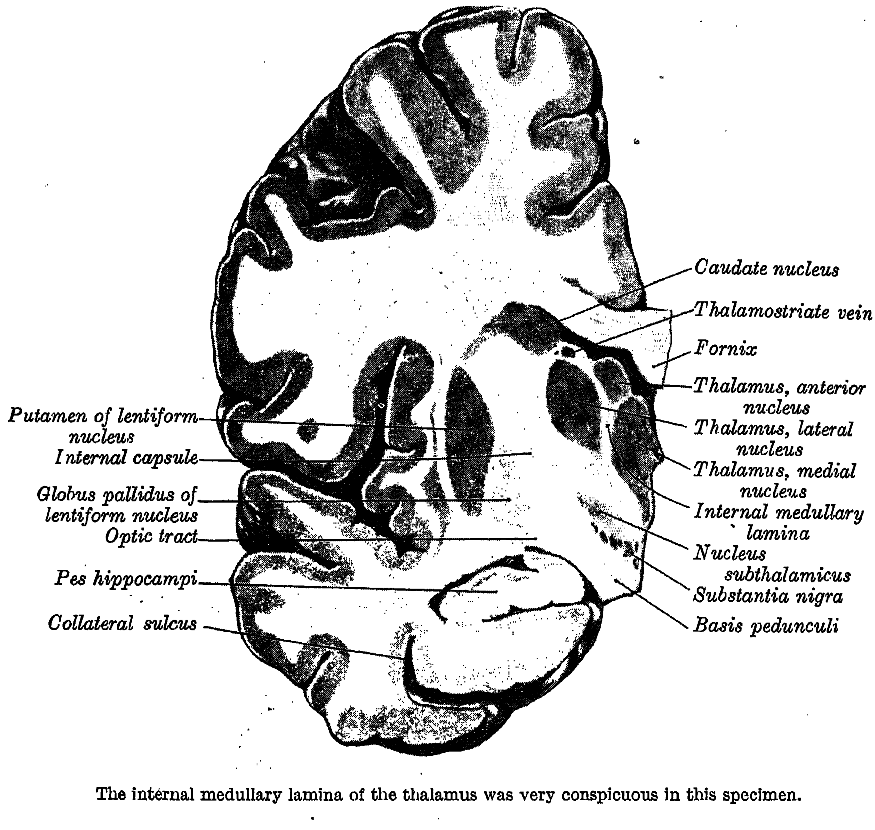
(p. 992), and probably also to the caudate nucleus and the putamen of the lentiform nucleus.

The lateral nucleus of the thalamus reaches its greatest development in the anthropoid apes and man. It can be subdivided into a ventral portion, a lateral portion proper, an arcuate portion, and the pulvinar. The *ventral portion* receives the great majority, if not all, of the fibres which ascend in the medial lemniscus (proprioceptive and discriminative or gnostic sensibility), and in the spinal and trigeminal lemnisci (pain and temperature). Its efferent fibres traverse the posterior limb of the internal capsule and terminate in the cortex of the post-central gyrus (p. 993), where these somesthetic impressions can be localised, analysed, and dealt with in the light of past experience. The connexions of the *lateral portion* are still obscure, but it is probably linked up with the medial nucleus, and the ventral portion and the pulvinar. Its efferent fibres, for the most part, proceed through the posterior limb of the internal capsule to reach the postcentral area (p. 993). Those which pass below the lentiform nucleus intervene between it and the anterior perforated substance, and constitute the *ansa peduncularis.* The *arcuate portion* lies between the ventral portion and the medial nucleus. In the macaque monkey it apparently receives afferent fibres from the tongue, mouth and lips regions through the trigeminal lemniscus,

and it projects on to the granular cortex which lies immediately below the lower limit of the motor cortex in that animal (Le Gros Clark, *Phil. Trans.*, B., 1937).

The *pulvinar* occupies the posteromedial portion of the lateral nucleus, and it was formerly believed to act as a cell-station on the visual pathway to the occipital cortex. It is now known that, after extirpation of the eyes, relatively few degenerated fibres can be traced into the pulvinar. Further, its efferent fibres proceed, for the most part, to the cortex of the lips of the lateral sulcus, over an area which extends from the audito-sensory cortical area (p. 995) to the middle part of the inferior parietal lobule. Its projection on to the last-named region is believed to be essential for that component of stereognosis which requires the association of visual with tactile memories, but it is clear that if, as seems certain, the pulvinar functions in this way it must receive afferent fibres either from the visual cortex or from the lateral geniculate body or from both. A few fibres from the

FIG. 873.—A coronal section through the right cerebral hemisphere. Anterior aspect.



The internal medullary lamina of the thalamus was very conspicuous in this specimen.

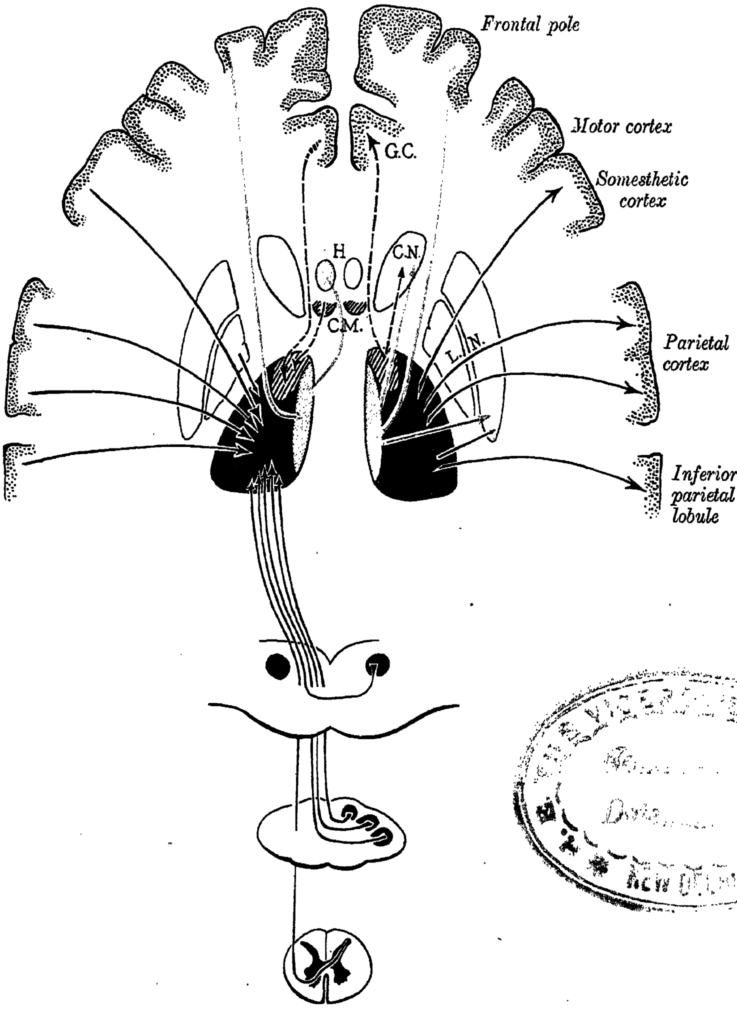
immediate vicinity of the geniculate bodies pass to the peri- and parastriate areas of the occipital cortex.

Functional significance of the thalamus.*—The thalamus is the most important of the subcortical correlation centres. Into it stream impulses from the olfactory apparatus, the visual apparatus, the somatic receptors of all kinds and the splanchnic receptors. In the thalamus these impulses are correlated with one another before they are transmitted to the cerebral cortex, but the correlation which occurs in the thalamus is something more than the simple interaction of nervous impulses, for there is good ground for supposing that the activities of the thalamus enter into and are appreciated by consciousness. It is certain that the higher forms of sensibility such as discriminative sensibility require the co-operation of the cerebral cortex, but cruder forms of sensibility, especially pain, are consciously experienced when the connexions existing between the thalamus and the cortex have been destroyed.

* For a full analysis of current views on the connexions and functions of the thalamus see "Functional Localisation in the Thalamus and Hypothalamus," W. E. le Gros Clark, *Journal of Mental Science*, March, 1936.

As already stated (p. 957), the medial nucleus of the thalamus receives afferents from the hypothalamus, which contains higher centres associated with the viscera. The cortical connexions of this nucleus bring visceral activities under the influence of the cortex and so provide a mechanism whereby the cortex is enabled to control or inhibit emotional and instinctive reactions which would otherwise result from visceral stimuli.

FIG. 874.—Scheme to show the principal connexions of the thalamus.



C.M. = Corpora mamillaria : C.N. = Caudate nucleus : G.C. = Gyrus cinguli : H. = Nuclei of hypothalamus : L.N. = Lentiform nucleus.
The lateral nucleus is shown in *black* : the medial nucleus in *blue* : and the anterior nucleus is *shaded*.

Fishes and, to a lesser extent, amphibia are dependent on the palæothalamus for the appreciation of harmful or beneficial stimuli. Co-ordinated responses arise in the thalamus and subthalamic region and result in the avoidance or the quest of such stimuli, as the case may be. In man such stimuli receive recognition in the thalamus, but the association areas of the cerebral cortex are necessary for their analysis and localisation.

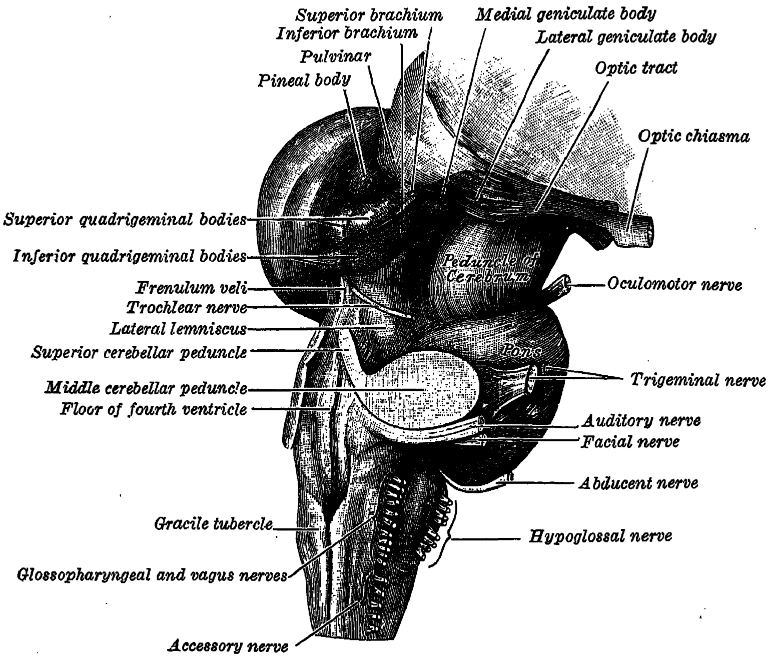
The **metathalamus** (fig. 875) comprises the geniculate bodies, which are two in number—a medial and a lateral—on each side.

The *medial geniculate body* lies under cover of the pulvinar of the thalamus, and lateral to the corpora quadrigemina. Oval in shape, with its long axis

directed forwards and laterally, it is lighter in colour and smaller in size than the lateral geniculate body. Through the inferior brachium it receives auditory fibres from the inferior corpus quadrigeminum and from the lateral lemniscus. Its cells send a relay of similar fibres to the cortex of the temporal lobe. The medial geniculate body is connected with its fellow and with the inferior corpus quadrigeminum of the opposite side by commissural fibres, which pass through the posterior part of the optic chiasma and run in the medial roots of the optic tracts.

The *lateral geniculate body* is an oval elevation on the lower surface of the lateral part of the posterior end of the thalamus, and is connected with the superior corpus quadrigeminum by the superior brachium. It receives most

FIG. 875.—The hind-brain and the mid-brain. Posterolateral aspect.



of the fibres of the optic tract, the remainder passing through the superior brachium to the superior corpus quadrigeminum, and very few, if any, terminating in the pulvinar. Its cells are large and pigmented, and are arranged in six laminæ, alternate laminæ being associated with the right and left eyes respectively.* Their axons pass through the optic (thalamo-occipital) radiation to the visual area in the occipital cortex.

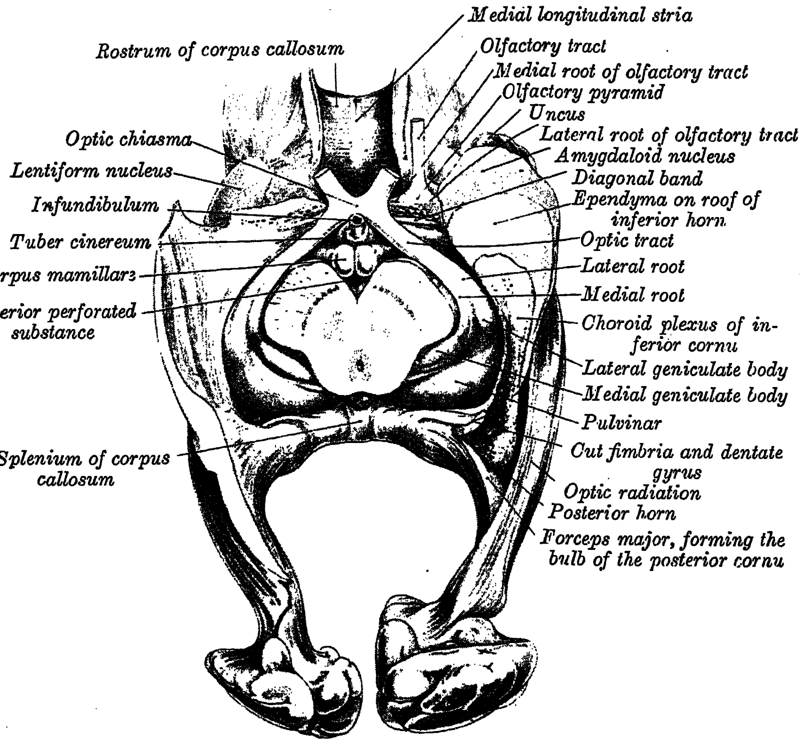
The superior corpus quadrigeminum, the pulvinar and the lateral geniculate body are termed the lower visual centres, but it must clearly be understood that *the great majority, if not all, of the fibres which are destined for the visual cortex are relayed in the lateral geniculate body.* Brouwer and Zeeman excised portions of the retina in rabbits, cats and monkeys and were unable to trace any degenerated fibres of the optic tract into the pulvinar. Further, they were able to localise the retinal fibres in definite areas of the lateral geniculate body. Fibres from the upper half of the retina are connected to its medial portion, those from the lower half of the retina to its lateral portion. Macular fibres occupy the central zone, and the area allotted to them is a large one (fig. 883). Those fibres from the nasal side of the retina which are concerned with monocular vision only are found in the ventral part of the lateral geniculate body, and occupy a narrow strip-like area (fig. 883).

The epithalamus comprises the trigonum habenulæ, the pineal body, and the posterior commissure.

* W. E. le Gros Clark and G. G. Penman, *Proc. Roy. Soc.*, B, 1934, cxiv.

The *trigonum habenulæ* is a small, depressed, triangular area, situated in front of the superior quadrigeminal body and medial to the posterior part of the thalamus, from which it is separated by the sulcus habenulæ (fig. 871). It contains a group of nerve-cells named the *habenular nucleus* (habenular ganglion). Afferent fibres are conveyed to the ganglion by the *stria habenularis* (stria medullaris thalami), which is formed at the anterior end of the thalamus by fibres which ascend from the anterior perforated substance and by fibres from the anterior column of the fornix. The stria then passes backwards on the medial surface of the thalamus (p. 955) and forms the medial boundary of the trigonum habenulæ. Some of the fibres cross in the peduncle of the pineal body and reach the habenular nucleus of the opposite side. They constitute the

FIG. 876.—A dissection of the brain from below, showing the metathalamus and the optic tracts.



On the right side of the figure the inferior horn of the ventricle is exposed. The floor has been removed but the choroid plexus is *in situ* and obscures most of the roof.

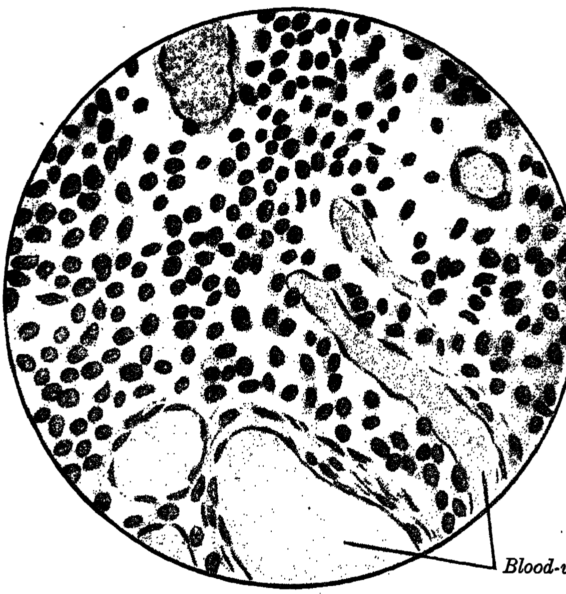
habenular commissure. Efferent fibres leave the ganglion and pass ventrally forming the *fasciculus retroflexus.* They descend medial to the red nucleus and end in the interpeduncular nucleus (interpeduncular ganglion) (p. 963), and some are described as reaching the substantia nigra of the mid-brain. The habenular nucleus and its afferent and efferent paths constitute a portion of the rhinencephalon.

The *pineal body* (figs. 871, 877) is a small, conical, reddish-grey body which lies in the depression between the superior quadrigeminal bodies. It is placed below the splenium of the corpus callosum, but is separated from it by the tela chorioidea of the third ventricle and the contained cerebral veins. It is enveloped by the lower layer of the tela, which is then reflected over the tectum (quadrigeminal lamina) (fig. 884). The pineal body measures about 8 mm. in length, and its base, directed forwards, is attached by a stalk or peduncle of white substance. The *stalk* divides anteriorly into two laminæ, a dorsal and a ventral, which are separated from each other by the pineal recess of the third ventricle. The ventral lamina is continuous with the posterior commissure and the dorsal lamina with the habenular commissure.

Structure (fig. 877).—The bulk of the parenchyma of the pineal gland consists of rounded cells, the so-called *pineal* cells, with irregular nuclei poor in chromatin. At birth a few neuroglia-cells and nerve-cells are present; the latter have scanty protoplasm and angular nuclei rich in chromatin. Connective tissue cells and fibrils appear during the first year, and gradually increase in quantity; the rate at which fibrosis takes place is very variable. Calcareous concretions are constantly present in the pineal body after the seventeenth year; spaces or cysts may also be present.*

The human pineal body is developed from the epiphysis, which grows out from the caudal end of the roof-plate of the diencephalon. In Cyclostome fishes the epiphysis gives rise to two diverticula, a parietal or parapineal and a pineal organ. Both these derivatives grow towards the dorsal surface of the head, and they become connected to the habenular region by a solid stalk containing nerve-fibres. Their vesicular extremities show a distinct resemblance to the optic vesicle. In Sphenodon, one of the most primitive reptiles, the parietal organ reaches the dorsal surface of the head and constitutes the parietal eye,

FIG. 877.—A section through the pineal body of a child aged 13 months. Stained with hæmatoxylin and eosin. ×400.



possessing a well differentiated cornea, lens and retina. The pineal organ, on the other hand, remains as a hollow, glandular structure which pours its secretion into the third ventricle. In mammals the parietal organ disappears at an early stage of embryonic life, and the pineal body is homologous with the pineal organ.

The *posterior commissure* is a small band of fibres crossing the median plane on the dorsal surface of the upper end of the aqueduct of the mid-brain, covered by the ventral lamina of the peduncle of the pineal body. Its fibres acquire their medullary sheaths early, but their connexions have not been definitely determined. Most of them have their origin in the *nucleus of Darkschewitsch* (p. 947), which lies in the ventral grey matter of the upper end of the aqueduct of the mid-brain, ventrimedial to the upper end of the oculomotor nucleus; some are probably derived from the posterior part of the thalamus and from the superior quadrigeminal body; others are believed to be continued downwards into the medial longitudinal bundle.

The **hypothalamus** (fig. 881) includes: (1) the subthalamic tegmental region; (2) the structures forming the floor of the third ventricle, viz. the posterior perforated substance, the corpora mamillaria, tuber cinereum, infundibulum, hypophysis cerebri and optic chiasma; and (3) the anterior part of the lateral wall of the third ventricle, below and in front of the thalamus.

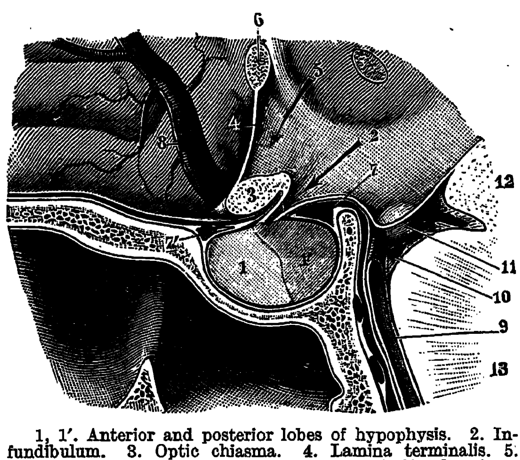
* Consult an abstract of an article by K. H. Krabbe in the *Review of Neurology and Psychiatry*, Edinburgh, 1915, xiii. 300.

(1) The *subthalamic tegmental region* consists of the forward continuation of the tegmentum beneath the posterior part of the thalamus. The red nucleus and the substantia nigra can be followed into its posterior part, where they gradually diminish, and disappear behind the corpus mamillare. The fibres of the medial lemniscus, on their way to enter the ventral surface of the thalamus, lie first lateral and then dorsal to the red nucleus. Some of the ascending branches of the fibres of the superior cerebellar peduncle pass directly into the thalamus, but the majority end in the red nucleus. A small, brownish-coloured nucleus, named the *subthalamic nucleus*, appears on the dorsal surface of the base of the cerebral peduncle. Shaped like a biconvex lens when seen in coronal sections of the brain, the nucleus lies dorsilateral to the upper end of the substantia nigra and extends backwards as far as the lateral aspect of the red nucleus. Dorsally (or above) it is related to the lateral nucleus of the thalamus, from which it is separated by a narrow area, termed the *zona incerta* (fig. 872). The fibre connexions of the subthalamic nucleus are still obscure, but it is known to receive a substantial bundle of fibres from the *ansa lenticularis*, which arise from the globus pallidus of the lentiform nucleus and enter its dorsal aspect, after intersecting the fibres of the internal capsule. In addition it receives afferents from some of the nuclei of the hypothalamus and probably represents the principal motor co-ordinating centre of that region. Clinical evidence indicates that destruction of the subthalamic nucleus is associated with uncontrollable movements, choreic in type, and exceedingly violent in character.

(2) *The structures forming the floor of the third ventricle.*—The *posterior perforated substance* is a small area of greyish substance which lies on the basal surface of the brain in the interval between the diverging cerebral peduncles. It is pierced by a number of small apertures which transmit the posteromedial central branches of the posterior cerebral arteries. In its posterior part it contains a small nucleus, named the *interpeduncular nucleus* (interpeduncular ganglion), in which the fasciculus retroflexus ends (p. 961). Superiorly the posterior perforated substance forms a small part of the floor of the third ventricle.

The *corpora mamillaria* (fig. 836) are two round white masses, each about the size of a small pea, placed side by side below the grey matter of the floor of the third ventricle in front of the posterior perforated substance. Each consists of white matter externally and of grey matter internally, the cells of the latter forming two nuclei, a *medial* of small and a *lateral* of large cells. The white matter is mainly formed by the fibres of the anterior columns of the fornix, which descend to the base of the brain and end partly in the corpora mamillaria. From the cells of the medial nucleus a bundle of fibres arises and divides into a *mamillo-thalamic tract*, which passes upwards into the anterior nucleus of the thalamus, and a *mamillo-tegmental tract*, which is directed downwards into the tegmentum. The fibres of the latter may arise as collaterals of the fibres of the mamillothalamic tract or they may arise independently. Afferent fibres run forwards to the lateral nucleus from the tegmentum and constitute the peduncle of the mamillary body.

Fig. 878.—A sagittal section through the hypophysis cerebri, in situ. Schematic. (Testut.)



1, 1'. Anterior and posterior lobes of hypophysis. 2. Infundibulum. 3. Optic chiasma. 4. Lamina terminalis. 5. Optic recess. 6. Anterior commissure. 7, 7'. Circular sinus. 8. Anterior cerebral artery. 9. Basilar artery. 10. Posterior cerebral artery. 11. Corpus mamillare. 12. Cerebral peduncle. 13. Pons.

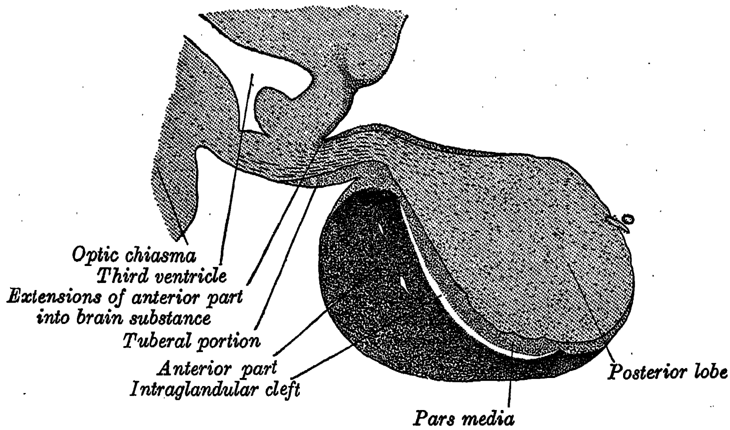
The corpora mamillaria form important cell-stations in the rhinencephalon. Olfactory impressions travelling from the hippocampus (p. 986) via the fornix

are relayed to the thalamus by the mamillothalamic tract, and can there be correlated with somesthetic and, probably, other visceral impressions. Thence the connexions of the thalamus with the corpus striatum offer a channel for the resulting co-ordinated motor response. The mamillotegmental tract affords a shorter pathway to the brain-stem for effector responses, and Kappers suggests that the snuffling of herbivorous animals when feeding is brought about by this pathway.

The *tuber cinereum* is a hollow eminence of grey matter which is situated between the corpora mamillaria behind and the optic chiasma in front. From its under surface, which is covered by the tuberal part of the hypophysis cerebri (p. 965), a hollow conical process, termed the infundibulum, projects downwards and is attached to the posterior lobe of the hypophysis. On each side the tuber cinereum is continuous with the anterior perforated substance, but it is separated from it on the basal surface of the brain by the optic tract.

The region occupied by the tuber cinereum is much more elaborated in fishes, and it owes its importance to its intimate relationship to the mouth and

FIG. 879.—A median sagittal section through the hypophysis cerebri of an adult monkey. Semidiagrammatic. (Herring.)



its consequent association with the sense of taste (Tilney). The dominance of the gustatory by the olfactory sense in air-breathing vertebrates is accompanied by a reduction in the development of this part of the hypothalamus, although several nuclei and commissural pathways have been described. It is in this region that the nervus terminalis (p. 1037) is attached, and the fact that it contains sympathetic fibres is not surprising in the light of recent work on the hypothalamus (p. 966).

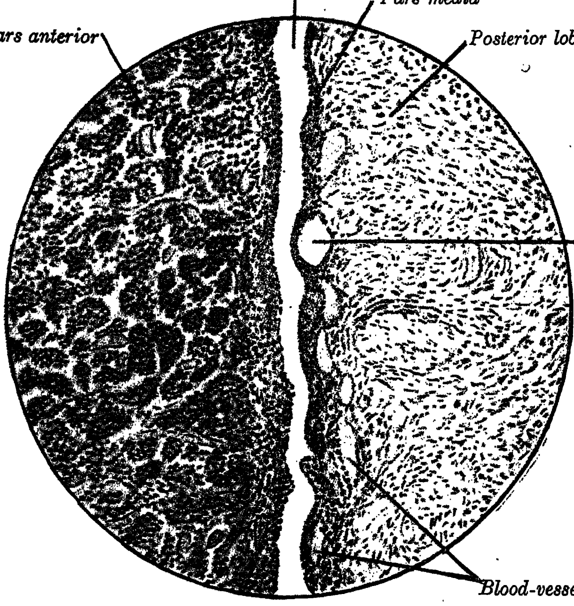
The *hypophysis cerebri* (fig. 879), is a reddish-grey, somewhat ovoid body, measuring about 12 mm. in its transverse, and 8 mm. in its anteroposterior diameter. It is attached to the end of the infundibulum, and is situated in the hypophyseal fossa of the sphenoid bone, where it is retained by a circular fold of dura mater, which is termed the *diaphragma sellæ*; this fold almost completely roofs in the fossa, leaving only a small central aperture through which the infundibulum passes, and it separates the anterior part of the upper surface of the hypophysis cerebri from the optic chiasma (fig. 878). On each side, the hypophysis cerebri is related to the cavernous sinus and the structures which it contains (p. 819). Inferiorly, it is separated from the floor of the fossa by a large, partially loculated, venous sinus, which communicates freely with the circular sinus.

The infundibulum, which is directed downwards and forwards, contains a funnel-shaped recess from the cavity of the third ventricle, and is surrounded (fig. 879) by an upward extension from the anterior lobe of the gland.

The hypophysis consists of an anterior and a posterior lobe, which differ in their development and structure (fig. 880). The *anterior lobe* is the larger,

and is somewhat kidney-shaped, the concavity being directed backwards and embracing the posterior lobe. It is developed from a diverticulum of the ectoderm of the primitive buccal cavity or stomodæum (p. 166), and consists of an anterior and a posterior part, separated from each other by a narrow cleft, which represents the remnant of the cavity of the diverticulum. The *anterior part* is extremely vascular and consists of granular epithelial cells of varying size and shape, arranged in cord-like trabeculæ or alveoli and separated by large, thin-walled blood-vessels. It is continuous above with the *tuberal portion*, which surrounds the infundibulum (fig. 879) and covers the tuber cinereum. The posterior part of the anterior lobe fuses with the anterior surface of the posterior lobe, forming the *middle part* (pars intermedia) of the hypophysis. It contains a few blood-vessels and consists of finely granular cells, between which are small masses of colloid material. The *posterior lobe*, which constitutes the *posterior part* of the hypophysis, is developed as a down-growth from the

FIG. 880.—A section of the hypophysis cerebri. × 100.



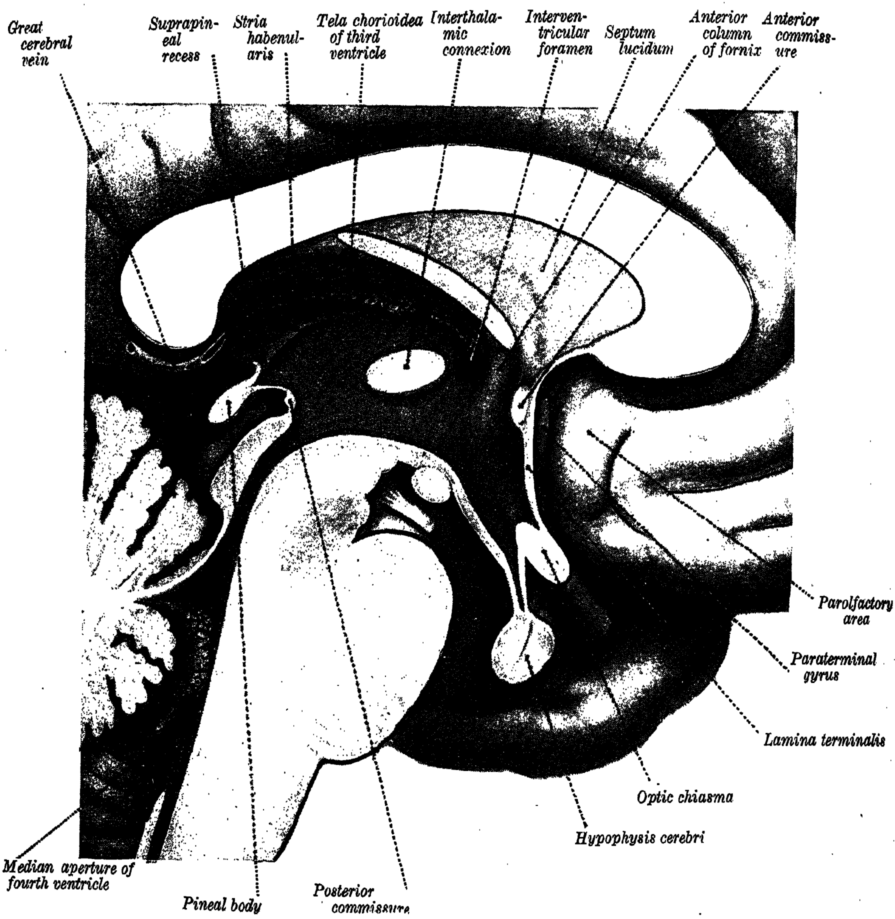
floor of the diencephalon, and during early fœtal life contains a cavity continuous with that of the third ventricle. In some animals (e.g. cat) this cavity persists throughout life. Although of nervous origin the posterior lobe contains no nerve-cells, but it receives nerve fibres from some of the nuclei of the hypothalamus. It consists of neuroglia-cells and fibres, and is invaded by cell-columns which grow into it from the middle part; imbedded in it are scattered masses of a colloid substance histologically similar to that found in the thyroid gland. In certain of the lower vertebrates (e.g. fishes) nervous structures are present, and the lobe is of large size. It draws a somewhat limited blood-supply from the internal carotid arteries.

Applied Anatomy.—Enlargement of the hypophysis cerebri and of the cavity of the sella turcica is found in the rare disease *acromegaly*, which is characterised by gradual increase of the size of the face, hands, and feet, with headache and often a peculiar type of blindness. This blindness is due to the pressure of the enlarging hypophysis on the inferior aspect of the optic chiasma (fig. 878). The pressure causes atrophy of the nerve-fibres coming from the lower nasal quadrants of the retinæ; with the result that the patient loses the upper temporal quadrants of his fields of vision while retaining his nasal fields (bitemporal quadrantic hemianopia).

The *optic chiasma* is described on p. 967.

(3) The *anterior part of the lateral wall of the third ventricle* is separated from the thalamus, above and behind, by the hypothalamic sulcus (p. 970); posteriorly it covers the terminal (lower) part of the anterior column of the fornix (fig. 881). In this part of the hypothalamus several nuclei have been identified and described and evidence which associates them with the activities of the viscera is gradually accumulating. Further the relationship between some of these nuclei and the hypophysis is very intimate, and the whole hypothalamus is now generally regarded as a complex neuroglandular mechanism

FIG. 881.—Part of a median sagittal section through the brain. Compare with fig. 884.



Red=pia mater, cut edge; Blue=ependyma.

which is concerned with the regulation and co-ordination of visceral activities. In its posterior part it contains the highest centres which have hitherto been identified in connexion with the sympathetic nervous system.

In recent years the hypothalamus has been the subject of much investigation, both anatomical and experimental, and, owing to the researches of Ransom, Cushing, Beattie and many others,* it is possible to speak with some certainty on particular aspects of its functional activity.

(1) Some, at least, of the activities of the hypophysis are controlled by hypothalamic nuclei, several of which (notably the *supra-optic nucleus*, which covers the upper surface of the optic chiasma) send efferent fibres to terminate in the posterior lobe. Experimental

* For a full list of references, consult papers by S. W. Ransom (*Bulletin of the New York Academy of Medicine*, May, 1937) and W. E. le Gros Clark (*Journal of Mental Science*, March, 1936).

section of these fibres is followed by atrophy of the posterior lobe and is associated with the condition of diabetes insipidus, which can be controlled by the administration of posterior lobe extract. From these experiments, which have been fully confirmed, it may be inferred that normally the posterior lobe secretes an antidiuretic hormone which regulates the outflow of water from the kidney.

(2) All the signs of sympathetic activity, acceleration of heart, etc., can be obtained on electrical stimulation of an area in the lateral wall of the third ventricle immediately above the mamillary body. This area contains a well-defined group of nerve cells, termed the *posterior hypothalamic nucleus*, which send their efferents upwards to the medial nucleus of the thalamus (p. 957) and caudally into the brain-stem. The precise course of these fibres in the brain-stem is uncertain. Ransom believes that they travel in the lateral part of the substance of the tegmentum, but most authorities hold that they descend close to the floor of the fourth ventricle in a bundle often termed the fasciculus longitudinalis dorsalis of Schutz.

(3) The hypothalamus is closely connected with the sleep mechanism. Destructive lesions, situated in the depths of the hypothalamic part of the lateral wall of the third ventricle in monkeys and just above and behind the mamillary body in cats, are associated with profound somnolence, and the grey matter in the last-named situation is extensively involved in the disease known as encephalitis lethargica.

(4) Evidence is rapidly accumulating to show that the temperature-regulating mechanism is placed in the hypothalamus. Lesions of the floor of the third ventricle between the infundibulum and the supra-optic nucleus are always associated with loss of temperature control, which may be complete.

(5) There is ground for believing that a parasympathetic centre is present in the hypothalamus, in front of the posterior hypothalamic nucleus and on a deeper plane, in a group of cells termed the *lateral hypothalamic nucleus*. By electrical stimulation of this nucleus, Beattie, Brow and Long produced many of the signs of parasympathetic activity, which were abolished on section of both vagus nerves.

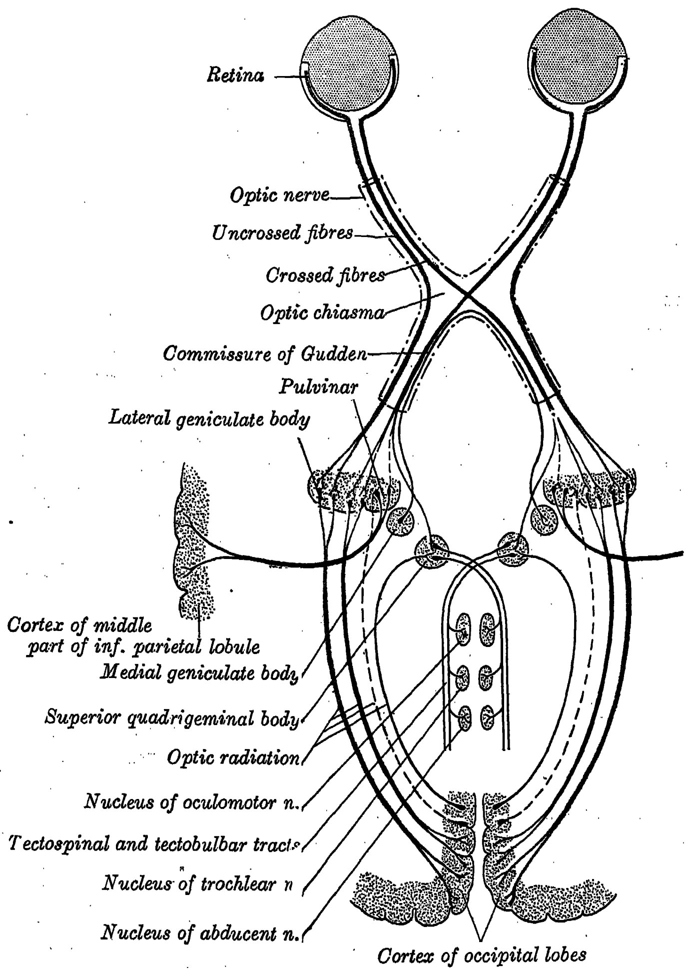
Optic chiasma.—The optic chiasma is a flattened, somewhat quadrilateral, bundle of nerve-fibres situated at the junction of the anterior wall of the third ventricle with its floor. Its anterolateral angles are continuous with the optic nerve, and its posterolateral angles with the optic tracts. The lamina terminalis (p. 968) is attached to its upper surface and is crossed, just above the chiasma, by the anterior communicating artery. Inferiorly the chiasma rests on the diaphragma sellæ just behind the optic groove (sulcus chiasmatis) of the sphenoid bone, and is thus in close relation to the hypophysis cerebri. Posteriorly it is related to the tuber cinereum and the infundibulum, below, and to the third ventricle above. Laterally it is related to the termination of the internal carotid artery and the anterior perforated substance. A small recess of the third ventricle, named the optic recess, passes downwards and forwards over its upper surface as far as the attachment of the lamina terminalis.

Most of the fibres of the optic chiasma take origin in the retina and reach the chiasma through the optic nerves. In the chiasma the fibres from the nasal half of each retina, including the nasal half of the macula, cross the median plane and enter the optic tract of the opposite side, while the fibres from the temporal half do not cross but pass backwards in the optic tract of the same side. The macular fibres from both eyes form a bundle, flattened from above downwards, which occupies the central part of the chiasma and separates the lower nasal quadrant fibres—which lie in the lower part of the chiasma—from the upper nasal quadrant fibres—which lie in the upper part of the chiasma. In the posterior part of the chiasma there is a strand of fibres, sometimes named the *commissure of Gudden*, which is not derived from the optic nerves. Its fibres arise in the medial geniculate body, enter the homolateral optic tract, cross in the chiasma and pass by the contralateral optic tract to reach the inferior corpus quadrigeminum and, possibly, the medial geniculate body of the opposite side. This commissure, therefore, forms no part of the visual pathway, but connects two lower auditory centres to each other.

Optic tracts.—The optic tracts (figs. 876 and 882) are continued backwards and laterally from the posterolateral angles of the chiasma. Each passes between the anterior perforated substance and the tuber cinereum, forming the anterolateral boundary of the interpeduncular space. The tract becomes flattened and winds round the upper part of the cerebral peduncle, to which it adheres closely. In this part of its course it is hidden from view on the basal surface of the brain by the uncus and the hippocampal gyrus. Reaching the

lateral geniculate body it divides into a medial and a lateral root. The medial root comprises the fibres of Gudden's commissure and enters the medial geniculate body. The lateral root consists mainly of afferent fibres which arise in the retina and undergo partial decussation in the optic chiasma, as already described, but it also contains a few fine efferent fibres which are passing forwards to terminate in the retina. Most of the fibres of the lateral root are

Fig. 882.—A scheme showing the connexions of the optic nerves and optic tracts.



The interrupted lines indicate connexions the existence of which is uncertain.

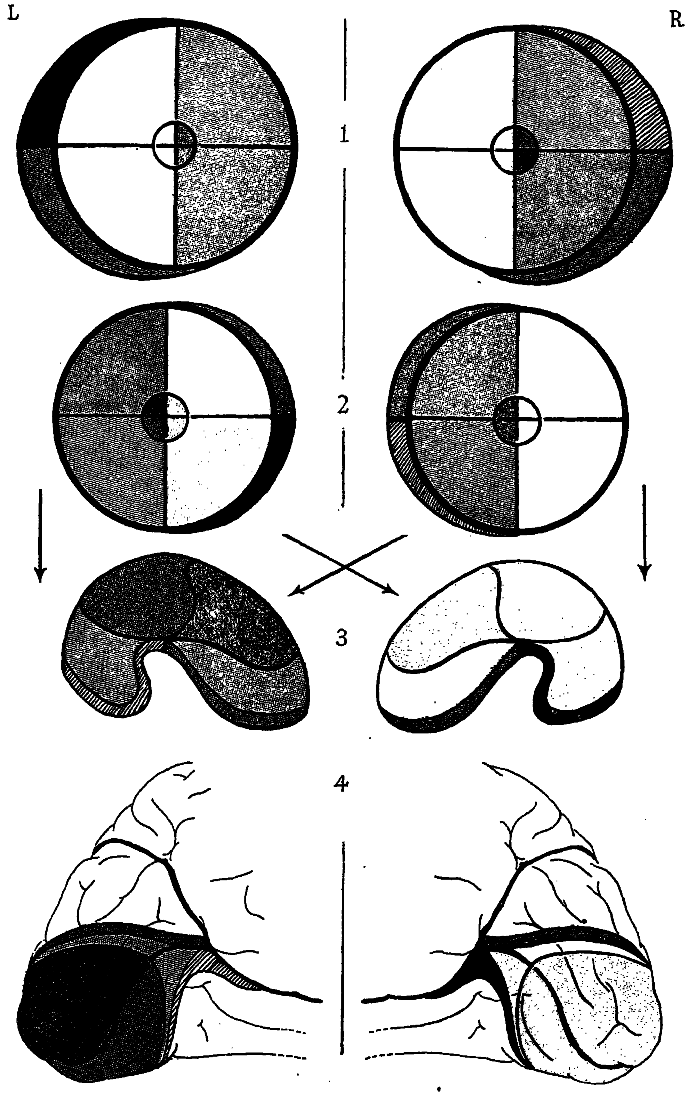
N.B.—*The dividing line between the decussating and the non-decussating fibres of the optic nerve passes vertically through the centre of the macula.*

found to end in the lateral geniculate body, but some sweep over the pulvinar and gain the superior quadrigeminal body.* It is very doubtful whether any of the fibres of the optic tract terminate in the pulvinar. New fibres arise from the nerve-cells in the lateral geniculate body, and pass through the posterior limb of the internal capsule. Emerging from the capsule as a broad bundle termed the optic radiation, the fibres of the second visual neurones sweep backwards and medially to reach the cortex of the occipital lobe of the cerebrum, where the higher or cortical visual centres are situated (p. 993). On their way they are separated from the posterior cornu of the lateral ventricle only by the tapetum of the corpus callosum.

* See footnote on p. 952.

Some of the fibres of the optic radiation take an opposite course, arising from the cells of the occipital cortex and passing to the superior quadrigeminal body, which therefore receives cortical in addition to retinal fibres. From the superior quadrigeminal body new fibres arise and travel by the tectobulbar and

FIG. 883.—A diagram to show the projection of the visual fields on the retinæ, lateral geniculate bodies and striate areas of the cortex. (Modified from S. Polyak, *Publications in Anatomy*, Univ. of California Press.)



1 = Fields of vision. 2 = Retinæ, coloured to correspond with 1. 3 = Coronal section of lateral geniculate body. 4 = Projection of lateral geniculate body on to the visual cortex. The arrows indicate the paths of the fibres in the optic chiasma.

Darker shades are used for the macular areas, and lighter shades for the peripheral retina. The peripheral strips on the nasal side of each retina are differently coloured on the two sides; they are associated with monocular vision only. The corresponding cortical areas for monocular vision are shown for the human brain and may be regarded as somewhat speculative.

tectospinal tracts to reach the nuclei of the third, fourth, sixth and eleventh cranial nerves, and the anterior grey column of the spinal cord. The superior quadrigeminal body constitutes a lower visual centre which is concerned through its retinal fibres with the light reflex * and, possibly, through its cortical

* Some authorities believe that the afferent fibres concerned in the light reflex pass direct from the optic tract to the Edinger-Westphal nucleus.

fibres with the reflex movements of the head and eyes which occur in response to visual stimuli.

The functional significance of the pulvinar with reference to the lower visual centres is explained on p. 958.

The Third Ventricle

The third ventricle (figs. 871, 881, 884), which is the derivative of the vesicle of the primitive fore-brain, is a median cleft between the two thalami. Behind, it communicates with the fourth ventricle through the aqueduct of the mid-brain, and in front with the lateral ventricles through the interventricular foramen. Somewhat triangular in shape with the apex directed backwards, it has a roof, a floor, an anterior and a posterior boundary, and two lateral walls.

The *roof* (fig. 884) is formed by a layer of ependyma which stretches between the upper edges of the lateral walls of the cavity and is continuous with the ependymal lining of the ventricle. It is covered by, and adherent to, a fold of pia mater, named the tela chorioidea of the third ventricle, from the under surface of which a pair of vascular fringed processes, named the *choroid plexuses of the third ventricle,* project downwards, one on each side of the median plane, and invaginate the epithelial roof into the ventricular cavity.

The *floor* (fig. 836) slopes downwards and forwards and is formed mainly by structures which belong to the hypothalamus ; from before backwards these are : the optic chiasma, the infundibulum and tuber cinereum, and the corpora mamillaria. Behind the last the floor is formed by the posterior perforated substance and by the tegmenta of the cerebral peduncles. The ventricle is prolonged downwards into the infundibulum as a funnel-shaped recess, termed the *infundibular recess.* The hypophysis cerebri is attached to the apex of the infundibulum.

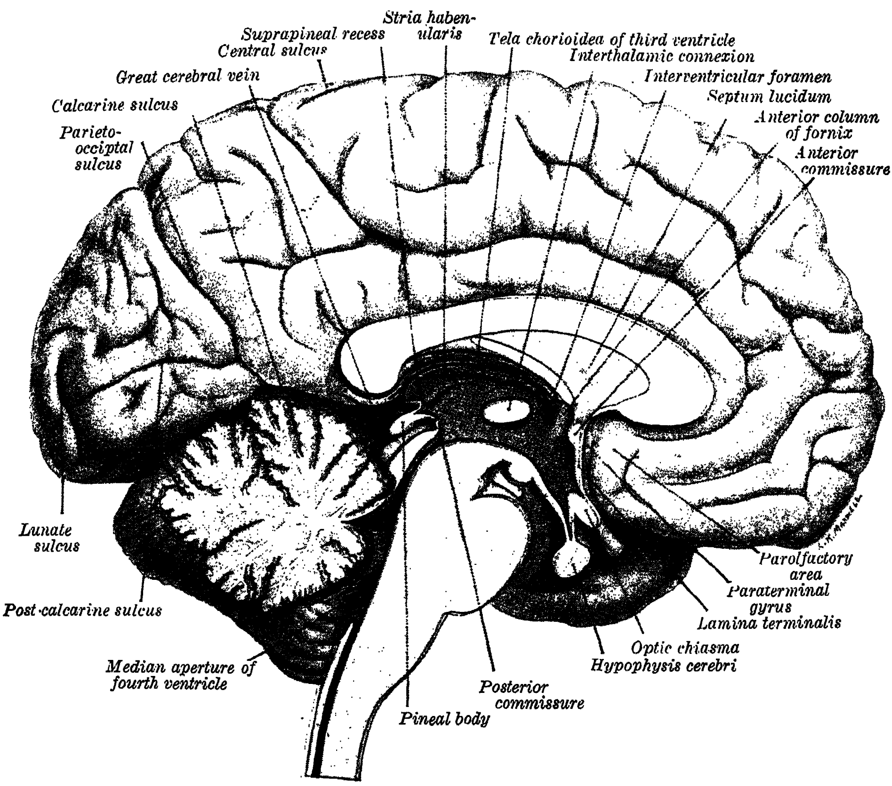
The *anterior boundary* (fig. 881) is constituted below by the *lamina terminalis,* which represents the cephalic end of the primitive neural tube. It forms a thin layer of grey matter stretching from the upper surface of the optic chiasma to the rostrum of the corpus callosum. In its upper part the anterior boundary is formed by the anterior columns of the fornix, which diverge as they pass downwards and sink into the lateral walls of the ventricle, and the anterior commissure (p. 1001), which crosses the median plane in front of them. At the junction of the floor and anterior wall, immediately above the optic chiasma, the ventricle presents a small angular recess or diverticulum, named the *optic recess.* Between the anterior columns of the fornix, and above the anterior commissure, is a second recess, sometimes termed the *vulva.* At the junction of the roof with the anterior and lateral wall of the ventricle is the *interventricular foramen* (foramen of Monro), through which the third and the lateral ventricles communicate with one another. It represents the site of the original diverticular outgrowth from the telencephalon which forms the cerebral hemisphere, and is relatively large and circular in a 10 mm. human embryo. In the adult, however, it is reduced to a somewhat crescentic slit, bounded in front by the curving anterior column of the fornix and behind by the convex anterior tubercle of the thalamus.

The *posterior boundary* (fig. 881) is constituted by the pineal body, the posterior commissure and the aqueduct of the mid-brain. A small recess, named the *pineal recess,* projects into the stalk of the pineal body, whilst in front of and above the pineal body a second recess, named the *suprapineal recess,* consists of a diverticulum of the epithelium which forms the ventricular roof.

Each *lateral wall* consists of an upper portion formed by the medial surface of the anterior two-thirds of the thalamus, and a lower formed by the hypothalamus and continuous with the grey matter of the ventricular floor. These two parts are separated from each other by the *hypothalamic sulcus,* which extends from the interventricular foramen to the aqueduct of the mid-brain, but is not always an obvious feature. The lateral wall is limited above by the ridge covering the stria habenularis (p. 955). The anterior columns of the

fornix curve downwards in front of the interventricular foramen, and then run in the lateral walls of the ventricle, where, at first, they form distinct prominences, but subsequently are lost to sight. The lateral walls are joined to each other across the cavity of the ventricle by a band of grey matter, named the *connexus interthalamicus* (massa intermedia) (p. 955). The area below the

FIG. 884.—A median sagittal section through the brain.



The pia mater, where divided, is shown in *red*; the ependyma is shown in *blue*.

hypothalamic sulcus constitutes an important part of the hypothalamus and has been described on p. 966.

The **interpeduncular fossa** (figs. 836, 887).—This is a somewhat lozenge-shaped area of the base of the brain, limited in front by the optic chiasma, behind by the anterosuperior surface of the pons, anterolaterally by the converging optic tracts and posterolaterally by the diverging cerebral peduncles. The structures contained in it have already been described; from behind forwards they are the posterior perforated substance (p. 963), corpora mamillaria, tuber cinereum, infundibulum, and hypophysis cerebri (p. 964).

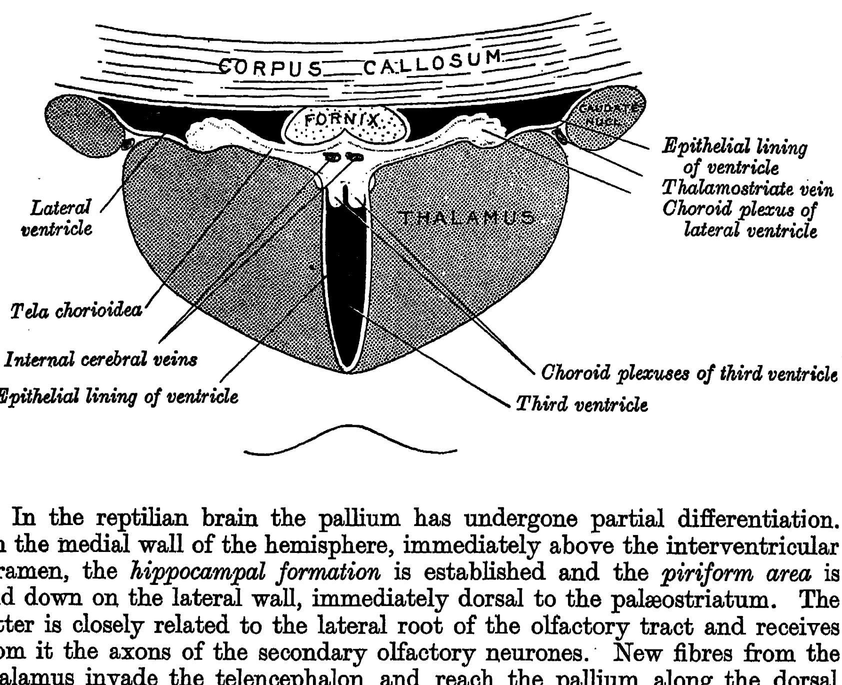
THE TELENCEPHALON

The expansion of the telencephalon or end-brain and the development of the two cerebral hemispheres in the human embryo have already been described (p. 115). In the most primitive vertebrates the anterior part of each cerebral hemisphere is constricted to form the *olfactory lobe*, which may become drawn forwards into a dilated extremity, termed the *olfactory bulb*. The latter is connected by a hollow stalk, named the *olfactory tract*, to an elevation on the wall of the hemisphere, which constitutes the *olfactory tubercle*. In the basal part

of each hemisphere a large nucleus is formed which derives its afferent fibres from the olfactory lobe and from the thalamus, and sends its efferent fibres to the brain-stem and the spinal cord. This basal nucleus is termed the *palæostriatum*, and it constitutes a motor centre where impulses from the olfactory bulb and the thalamus can be co-ordinated to produce the appropriate response. The remainder of the wall of the hemisphere constitutes the *pallium* or mantle, which, in higher forms, becomes elaborated and expanded in a very remarkable manner.

In the lowliest vertebrates the pallium shows very little differentiation, and it is merely a correlation area for gustatory impressions, which ascend from the hypothalamus, and for olfactory impressions, which stream into it not only from the olfactory lobe of the same side but also from the opposite side. Fibres from opposite sides cross in the lamina terminalis and represent the oldest commissures of the fore-brain, viz.: the anterior commissure and the hippocampal commissure.

Fig. 885.—A coronal section through the lateral and third ventricles. The pia mater of the tela chorioidea is shown in *red* and the ependyma in *yellow*. Diagrammatic.

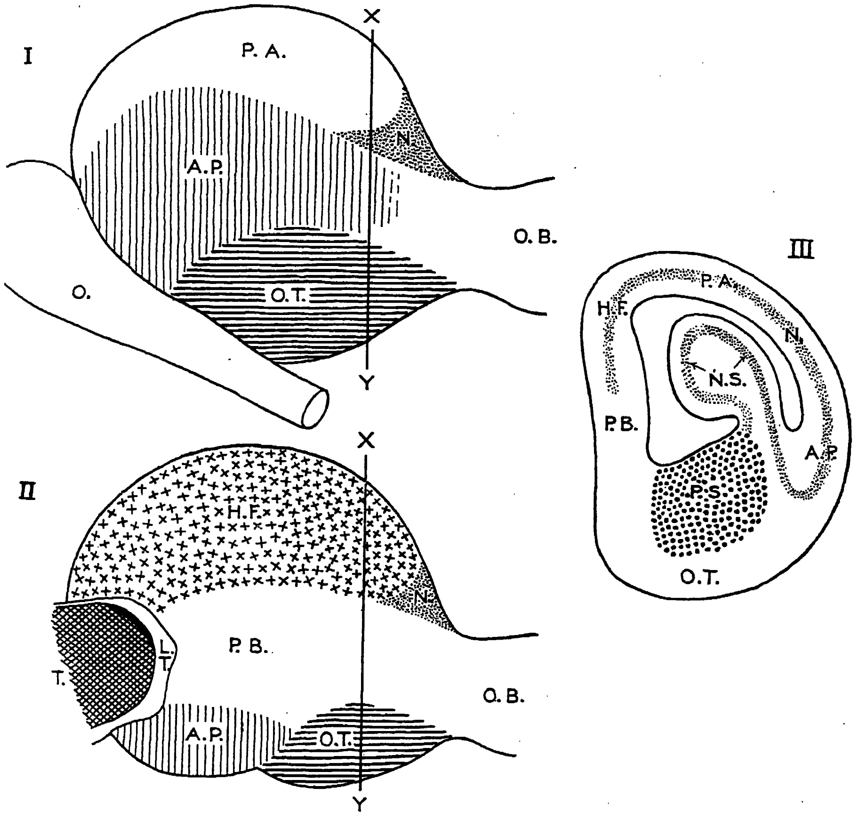


In the reptilian brain the pallium has undergone partial differentiation. On the medial wall of the hemisphere, immediately above the interventricular foramen, the *hippocampal formation* is established and the *piriform area* is laid down on the lateral wall, immediately dorsal to the palæostriatum. The latter is closely related to the lateral root of the olfactory tract and receives from it the axons of the secondary olfactory neurones. New fibres from the thalamus invade the telencephalon and reach the pallium along the dorsal and ventral margins of the piriform area. The latter preponderate at first, and the cells of the pallium in this situation multiply and grow centrally towards the cavity of the ventricle, in which they form a substantial longitudinal ridge. This ingrowth constitutes the *neostriatum* (of Kappers) (hypopallium of Elliot Smith), which lies dorsal to the palæostriatum and intimately related to it. Prior to the invasion of the telencephalon by thalamic fibres the whole behaviour of the animal was dominated by olfactory impressions, but after its invasion by fibres conveying gustatory, visual, tactile and other forms of sensibility, modifying influences are introduced, and it becomes imperative that the activities of the palæostriatum should be inhibited and regulated. This controlling action is exerted by the neostriatum.

At the same time other thalamic fibres reach the pallium along the dorsal and headward borders of the piriform area, and the cells in this situation increase enormously in number, and constitute the *neopallium*, as distinguished from the cortex of the hippocampal formation and the piriform area, which make up the *archipallium*. The cells of the neopallium lie between the hippocampal formation on the medial side and the piriform area on the lateral side.

In mammals the neopallium grows and expands, and in microsmatic animals, such as man, a part of this increase is accomplished at the expense of the archipallium, which is partly relegated to limited areas on the medial and inferior surfaces of the cerebral hemisphere and is partly overlapped and buried. With the appearance of new sensory centres in the neopallium, the simple movements which can be carried out by means of the corpus striatum (palæo- + neo-striatum) are insufficient to meet the demands and higher motor centres are therefore established in the neopallium for the control of the movements of the body. These motor centres are closely connected to the

Fig. 886.—Schematic representations of the cerebral hemisphere of a turtle, after Elliot Smith, *Journal of Anatomy*, vol. liii. (I) Lateral surface; (II) Medial surface; (III) Coronal section through I and II in the plane XY.



A.P., area piriformis; H.F., hippocampal formation; L.T., lamina terminalis; N., neopallium; N.S., neostriatum; O., optic tract; O.B., olfactory bulb; O.T., olfactory tubercle; P.A., parahippocampal area; P.B., paraterminal body; P.S., palæostriatum; T., thalamus.

sensory centres in the neopallium, and as these connexions increase in number, behaviour becomes less and less affected by olfactory impressions and more and more influenced by other forms of sensibility.

At first the higher sensory centres laid down in the neopallium adjoin one another, but they gradually become separated by the development of association areas, in which at first visual, olfactory and gustatory impressions can be correlated. The association of these different forms of sensibility with one another renders possible the registration of past experience so as to benefit the animal in its pursuit and selection of food. Its movements, therefore, become purposive, and a plastic element is introduced into its behaviour.

The addition of higher auditory centres and the expansion of the somesthetic centres are accompanied by the appearance of new association areas, all of which become linked up with the motor centres. As the neo-

pallium expands for these purposes behaviour becomes still more purposive and plastic.

The association areas have reached a much higher degree of expansion in man than in his nearest relatives, the anthropoid apes, and it is this feature in the structure of the human brain that has rendered possible the complexities of the intellectual life.

The earlier stages of the expansion of the neopallium are the result of the process of *telencephalisation*, by means of which higher centres are shifted forwards into the end-brain. The best example of this process is the appearance of the visual cortex in the occipital lobe, which takes over the higher visual centres formerly situated in the optic lobe or superior corpus quadrigeminum of the mid-brain.

Parts of the telencephalon.—The telencephalon includes: (1) the cerebral hemispheres, the commissures which connect them, and the cavities which they contain, and (2) the anterior parts of the hypothalamus and of the third ventricle (already described on pp. 966-969). Each cerebral hemisphere consists of an outer layer of grey matter, termed the cortex, an inner mass of white fibres, and certain buried basal nuclei. The cortex may further be subdivided into the derivatives of the neopallium and of the archipallium. The latter, with certain outlying structures such as the olfactory bulb, constitutes the rhinencephalon.

The Cerebral Hemispheres

The **cerebral hemispheres** form the largest part of the brain, and, when viewed together from above, assume the outline of an ovoid mass broader behind than in front, the greatest transverse diameter corresponding with a line connecting the two parietal tuberosities. The hemispheres are incompletely separated by a deep median cleft, named the *longitudinal cerebral fissure*, and each possesses a central cavity, termed the lateral ventricle.

The **longitudinal fissure of the cerebrum** contains a sickle-shaped process of dura mater, named the falx cerebri, and the anterior cerebral vessels. In front and behind the fissure completely separates the cerebral hemispheres from each other; in the middle, however, it only extends down to a great central white commissure, named the *corpus callosum*, which connects the hemispheres across the median plane.

The Surfaces of the Cerebral Hemispheres

Each cerebral hemisphere presents three surfaces: superolateral, medial, and inferior.

The *superolateral surface* is convex in adaptation to the concavity of the corresponding half of the vault of the cranium. The *medial surface* is flat and vertical and is separated from that of the opposite hemisphere by the longitudinal fissure and the falx cerebri. The *inferior surface* is of an irregular form, and may be divided into two parts: orbital and tentorial. The orbital part, formed by the orbital surface of the frontal lobe, is concave, and rests on the roof of the orbit and nose; the tentorial part is concavoconvex, and consists of the under surface of the temporal and occipital lobes; anterolaterally it is adapted to the corresponding half of the middle cranial fossa; posteromedially it rests upon the tentorium cerebelli, which intervenes between it and the upper surface of the cerebellum.

The three surfaces are separated by the following borders: (*a*) *superomedial*, between the superolateral and medial surfaces; (*b*) *inferolateral*, between the superolateral and inferior surfaces; the anterior part of this border separates the superolateral from the orbital surface of the frontal lobe, and is known as the *superciliary* border; (*c*) *medial occipital*, between the tentorial and medial surfaces; and (*d*) *medial orbital*, separating the orbital from the medial surface. The anterior end of the hemisphere is named the *frontal pole*; the posterior, the *occipital pole*; and the anterior end of the temporal lobe, the *temporal pole*. About 5 cm. in front of the occipital pole on the inferolateral border there is an indentation or notch, named the *pre-occipital notch*.

The surfaces of the hemispheres are moulded into a number of irregular eminences, named *gyri* or *convolutions*, and separated by furrows termed *sulci*.

The irregular character of the surfaces of the cerebral hemispheres is a very prominent feature, but it must be remembered that up to the end of the fourth month these surfaces are smooth and unbroken, like the surfaces of the brains of reptiles and birds. Thereafter localised depressions become apparent, and they deepen and extend over the surface to form the sulci. In certain situations these sulci develop along lines separating areas which differ from one another in the details of their microscopic structure and therefore probably in the functions which they subserve. Such sulci may therefore be termed *limiting sulci*, since they establish the limits of certain functional areas. The central sulcus (of Rolando) is an admirable example of a limiting sulcus, for it is set between two areas of cortex which differ in thickness so notably that the difference can be appreciated with the naked eye (fig. 891). In other situations sulci develop in the long axis of a rapidly growing homogeneous area and are termed *axial sulci*. The post-calcarine sulcus is situated in the centre of the striate area of the cortex and is related on both sides to the higher visual centres. In other situations, again, a sulcus may be situated between two surface areas of cortex which are structurally different, but its lip and not its floor may form the dividing line between the two areas. In these cases a third area is present in the wall of the sulcus and does not appear on the surface at all. Such a sulcus is termed an *operculated sulcus*, and this type is represented in the human brain by the lunate sulcus, which separates the striate from the peristriate areas on the surface and contains in its wall the submerged parastriate area, which really intervenes between them. These three varieties include all of the sulci which develop on the surface of the brain, with the exception of the lateral sulcus and the parieto-occipital sulcus. The former is the result of the slower expansion of the cortex of the insula and its consequent submersion by the adjoining cortical areas, which eventually come into contact with one another so as to delimit the lateral sulcus. The latter is brought about subsequent to the development of the corpus callosum. The posterior end of this great commissure has to convey not only the fibres from the occipital portions of the brain but also a large number of fibres from the temporal portions. As a result, a number of smaller axial and limiting sulci become crowded together and some of them become buried within the walls of the parieto-occipital sulcus. These two are really secondary sulci, since their occurrence depends on factors other than exuberant growth in closely adjoining areas.

Some of the sulci which indent the hemisphere are deep enough to produce corresponding elevations in the walls of the lateral ventricles. The calcarine sulcus, which produces the calcar avis of the posterior horn, and the collateral, which produces the *collateral eminence* in the inferior horn, are therefore termed complete sulci. There is, however, no special morphological or functional significance to be attached to the fact that while some sulci are complete others are incomplete.

The gyri and their intervening sulci are fairly constant in their arrangement; at the same time they vary within certain limits, not only in different individuals, but in the two hemispheres of the same brain. The convoluted condition of the surface permits of a great increase of the grey matter without the sacrifice of much additional space, and the number and extent of the gyri, as well as the depth of the intervening furrows, appear, within broad limits, to bear a direct relation to the intellectual powers of the individual.

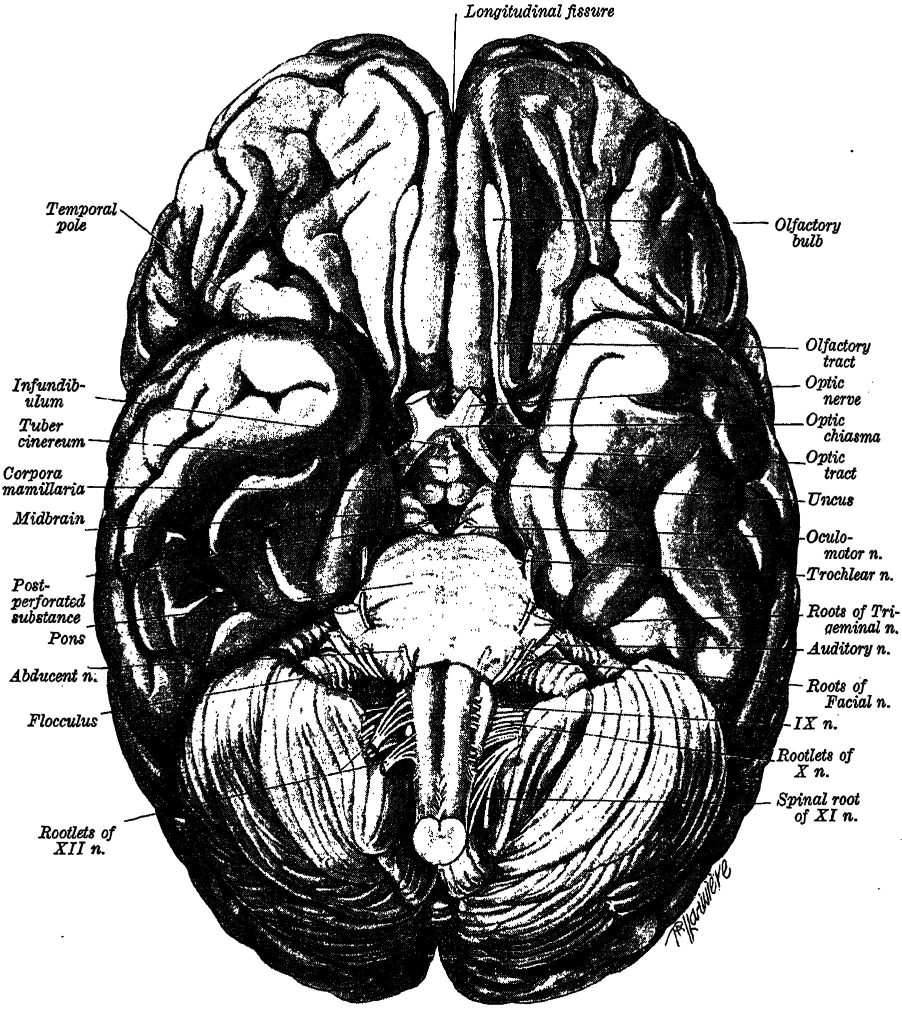
The superolateral surface of the cerebral hemisphere.—It is convenient for ease of description and for ease of reference to separate this surface into a number of lobes, but it must be remembered that this subdivision is purely one of convenience and that the lobes do not precisely correspond in surface extent to the cranial bones from which their names are derived.

The anterior part of the hemisphere is termed the **frontal lobe**, and, on this surface, it comprises the whole of the area which lies in front of the central sulcus and above the lateral sulcus. It is limited above by the superomedial and below and in front by the superciliary margin of the hemisphere.

The **lateral sulcus** (lateral fissure) (figs. 887 and 888) is a deep cleft situated on the inferior and lateral surfaces of the cerebral hemisphere. It consists of

a short stem which ends by dividing into three rami. The *stem* commences on the inferior surface at the lateral angle of the anterior perforated substance and extends laterally between the orbital surface of the frontal lobe and the anterior part of the temporal lobe. On reaching the lateral surface it divides into anterior horizontal, anterior ascending and posterior rami. The *anterior horizontal ramus* runs forwards for 2·5 cm. or less into the inferior frontal gyrus, while the *anterior ascending ramus* runs upwards for about an equal

FIG. 887.—The base of the brain.



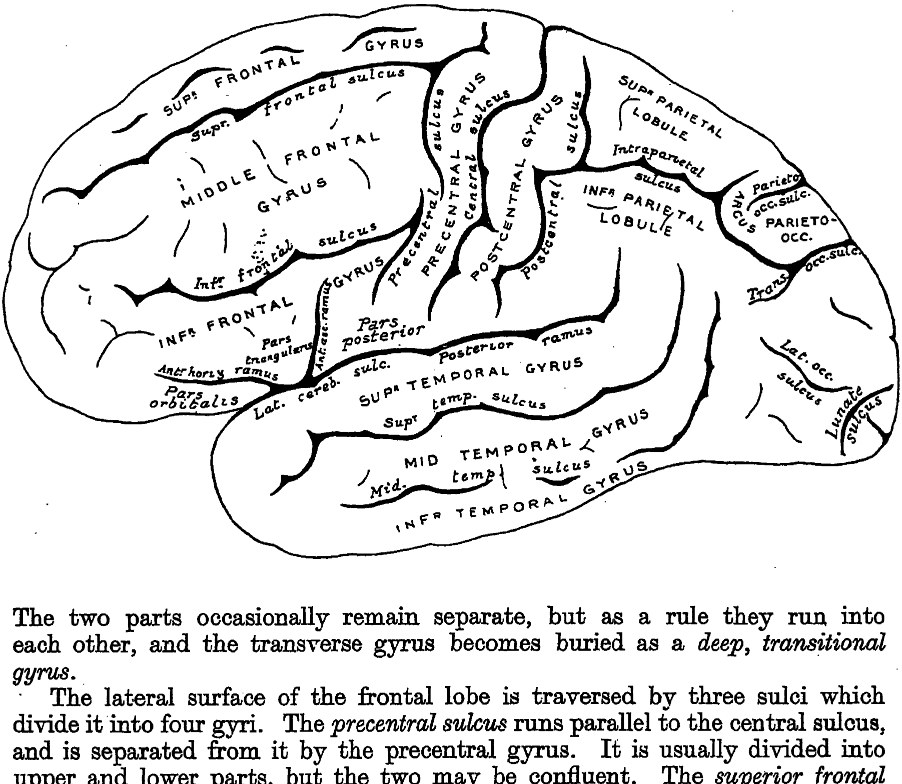
distance into the same gyrus. The *posterior ramus* is the longest division. It courses backwards and slightly upwards across the lateral surface for about 7 cm. before turning upwards to end in the parietal lobe. The floor of this sulcus is formed by the limen insulæ and the insula, and it conducts the middle cerebral vessels from the basal to the lateral aspect of the hemisphere.

The **central sulcus** (fig. 888) commences in or near the superomedial margin of the hemisphere a little behind the mid-point between the frontal and occipital poles. It runs sinuously downwards and forwards and ends a little above the posterior ramus of the lateral sulcus, from which it is always separated by an arched gyrus. The general direction of the sulcus makes an angle of rather less than 70° with the median plane. The central sulcus is a good example of a typical limiting sulcus, for it develops along the line which

separates the motor area of the cerebral cortex from the somesthetic area (p. 993).

When the central sulcus is opened up the opposed walls are found to be marked by a number of small gyri which interlock with one another after the manner of gears in mesh, and are therefore termed *interlocking gyri*. This arrangement provides additional cortical grey matter without any corresponding increase in the surface area on the lateral surface of the hemisphere. Another feature is brought to light by opening up the sulcus. The floor is not the same depth throughout its whole extent, for a little below the middle of the sulcus its walls are usually connected to each other by a buried, transverse gyrus. The explanation of this condition is found in the mode of development of the central sulcus. When it makes its appearance in the sixth month, it does so in two distinct portions, an upper and a lower, which are at first separated by a transverse gyrus connecting the precentral convolution to the postcentral.

Fig. 888.—The superolateral surface of the left cerebral hemisphere. Lateral aspect.



The two parts occasionally remain separate, but as a rule they run into each other, and the transverse gyrus becomes buried as a *deep, transitional gyrus*.

The lateral surface of the frontal lobe is traversed by three sulci which divide it into four gyri. The *precentral sulcus* runs parallel to the central sulcus, and is separated from it by the precentral gyrus. It is usually divided into upper and lower parts, but the two may be confluent. The *superior frontal sulcus* runs forwards and downwards from about the middle of the upper part of the precentral sulcus, while the *inferior frontal sulcus* runs parallel to it at a lower level. The portion of the frontal lobe which lies anterior to the precentral sulcus is thus divided into the superior, middle and inferior frontal gyri.

The *precentral gyrus*, which is bounded behind by the central sulcus and in front by the precentral sulcus, extends from the superomedial border of the hemisphere to the posterior ramus of the lateral sulcus. The large pyramidal cells of its posterior part (giant cells of Betz) give origin to the fibres of the important cerebrospinal (pyramidal) motor tract.

The *superior frontal gyrus* lies above the superior frontal sulcus, and is continuous over the superomedial margin of the hemisphere with the medial frontal gyrus on the medial surface. It is more or less completely subdivided into upper and lower portions by the paramedian sulcus which, however, is frequently interrupted by bridging gyri.

The *middle frontal gyrus* lies between the superior and the inferior frontal sulci. Its surface is broken by two or three small sulci which together constitute the *middle frontal sulcus*. Lesions of this gyrus result in interference with conjugate movements of the eyes.

The *inferior frontal gyrus* lies below the inferior frontal sulcus and is invaded by the anterior horizontal and the anterior ascending rami of the lateral sulcus. The areas grouped around these two rami constitute Broca's area and are associated with the motor element of speech. The portion lying below the anterior horizontal ramus is termed the *pars orbitalis*, and it curves round the superciliary margin to gain the orbital surface of the frontal lobe. The portion between the ascending and the anterior horizontal rami is termed the *pars triangularis*, while the portion lying behind the anterior ascending ramus forms the *pars posterior* (pars basilaris) and is continuous behind with the lowest part of the precentral gyrus.

The **temporal lobe** lies below the lateral sulcus. Behind it is limited by a line drawn from the preoccipital notch (p. 974) to the parieto-occipital sulcus, where it cuts the superomedial margin about 5 cm. in front of the occipital pole. The lateral surface of the temporal lobe is divided into three parallel gyri by two sulci.

The *superior temporal sulcus* begins behind the temporal pole and runs backwards and slightly upwards parallel to the posterior ramus of the lateral sulcus. Its posterior end curves upwards into the parietal lobe. The *inferior* (middle) *temporal sulcus* lies below and parallel to the superior sulcus. It is broken up into two or three short sulci, but its posterior end turns upwards into the parietal lobe, behind and parallel to the upturned end of the superior sulcus.

In this way the lateral surface of the temporal lobe is subdivided into three parallel gyri, the *superior*, *middle* and *inferior temporal gyri*. The superior temporal gyrus is continuous with the gyri which form the floor of the posterior ramus of the lateral sulcus. These are three or four in number, and they extend obliquely forwards and laterally from the circular sulcus which surrounds the insula. They are termed the *transverse temporal gyri* (fig. 890). The higher auditory centres are situated in the anterior transverse temporal gyrus and in the portion of the superior temporal gyrus with which it is in continuity (fig. 897).

The **parietal lobe** is bounded in front by the central sulcus and behind by the line joining the preoccipital notch to the superomedial margin at the point where it is cut by the parieto-occipital sulcus. Above, it is limited by the superomedial margin, and below by the posterior ramus of the lateral sulcus and a line drawn backwards to the posterior boundary from the point where the ramus turns upwards. It will be seen, therefore, that both the posterior boundary and the posterior part of the inferior boundary of the parietal lobe on this surface of the hemisphere are artificial.

The lateral aspect of the parietal lobe is subdivided into three areas by two sulci, termed the *postcentral sulcus*, which lies behind and parallel to the central sulcus, and the *intraparietal sulcus*, which passes backwards from the postcentral sulcus (fig. 889).

The *postcentral sulcus*, which may be divided into upper and lower parts, lies behind and parallel to the central sulcus. Inferiorly it ends above the posterior ramus of the lateral sulcus and in front of its upturned end. It divides the parietal lobe into an anterior part, termed the postcentral gyrus, and a large posterior part which is further subdivided by the intraparietal sulcus. The *intraparietal sulcus* commences in the postcentral sulcus about its middle or at the upper end of its lower subdivision. It extends backwards and downwards across the parietal lobe, dividing it into a superior and an inferior parietal lobule. Posteriorly, as the occipital ramus, it extends into the occipital lobe, where it joins the transverse occipital sulcus at right angles (fig. 888).

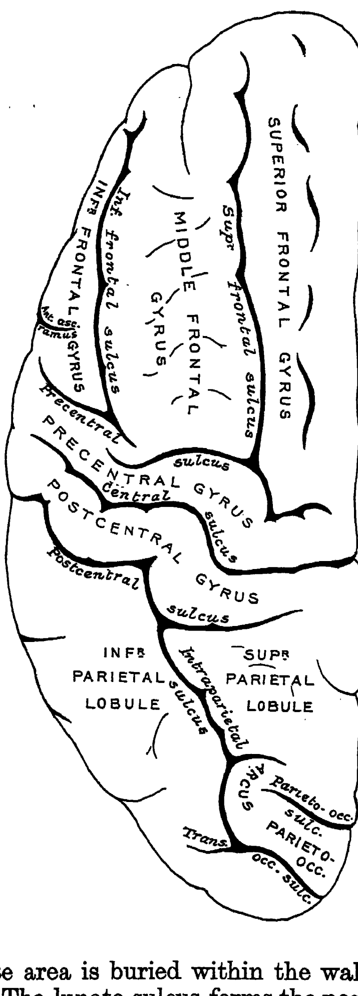
The *postcentral gyrus* lies between the central sulcus in front and the post-central sulcus behind. It contains the important higher centres for somesthetic sensibility (p. 993).

The *superior parietal lobule* extends between the superomedial margin of the

hemisphere and the intraparietal sulcus. In front it is continuous with the postcentral gyrus round the upper end of the postcentral sulcus, while posteriorly it frequently runs into the arcus parieto-occipitalis, which surrounds the external part of the parieto-occipital sulcus.

The *inferior parietal lobule* lies below the intraparietal sulcus and behind the lower part of the postcentral sulcus. It is divided into three parts. The *anterior part* (supra-marginal gyrus) arches over the upturned end of the lateral sulcus; it is continuous in front with the lower part of the postcentral gyrus and below and behind with the superior temporal gyrus. Occasionally it is limited posteriorly by a small sulcus, named the *sulcus intermedius primus*, which descends from the intraparietal sulcus. The *middle part* (angular gyrus) arches over the upturned end of the superior temporal sulcus and is continuous behind and below with the middle temporal gyrus; sometimes a small sulcus intermedius secundus forms its posterior boundary. The posterior part arches over the upturned end of the inferior temporal sulcus and extends on to the occipital lobe.

FIG. 889.—The superolateral surface of the left cerebral hemisphere. Superior aspect.



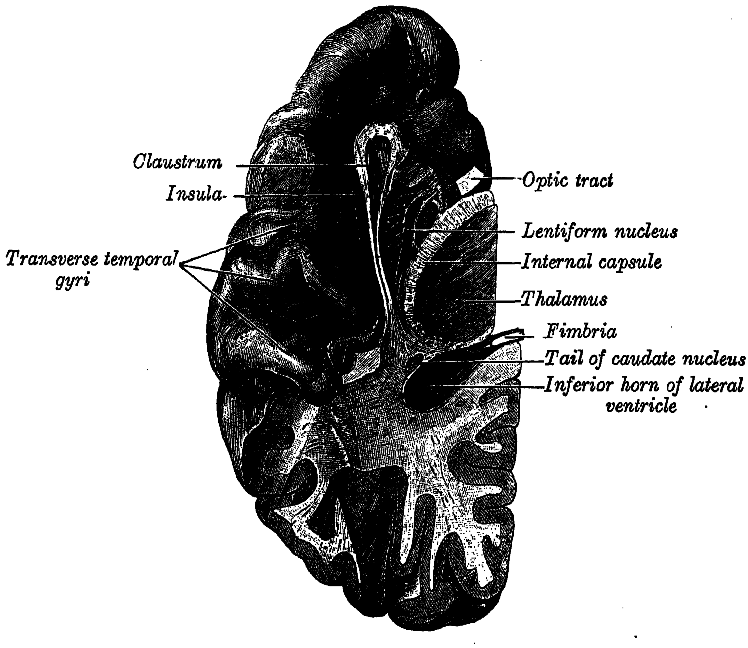
The part of the lateral surface which lies behind the line joining the pre-occipital notch to the parieto-occipital sulcus on the superomedial margin belongs to the occipital lobe. The *transverse occipital sulcus* descends from the superomedial margin behind the parieto-occipital sulcus and is joined about its middle by the intraparietal sulcus. Its upper portion forms the posterior boundary of the *arcus parieto-occipitalis*, an arched gyrus which surrounds the end of the parieto-occipital sulcus. The *lateral occipital* (*prelunate*) *sulcus* is a short sulcus which runs forwards on the lateral aspect of the occipital lobe and divides it into a *superior* and an *inferior occipital gyrus* (fig. 888). The *sulcus lunatus* is situated just in front of the occipital pole, but it is not invariably present. It is placed vertically and sometimes forms a ⊢ with the postcalcarine sulcus, although the two are more often separated from each other. The lips of the lunate sulcus, which is operculated in type, separate the striate from the peristriate area of the cortex, but the parastriate area is buried within the walls of the sulcus and intervenes between them. The lunate sulcus forms the posterior boundary of the *gyrus descendens* (Ecker), which lies behind the superior and inferior occipital gyri. Two curved sulci, named the superior and inferior polar sulci, are often present near the extremities of the lunate sulcus. The *superior polar sulcus* arches upwards on to the medial aspect of the occipital lobe from the neighbourhood of the upper limit of the lunate sulcus; the *inferior polar sulcus* arches downwards and forwards on to the inferior aspect from the lower limit of the same sulcus. These two polar sulci enclose semilunar extensions of the striate area (p. 993) and represent the expansion of the visual cortex in association with the formation of its large macular area * (p. 994).

The insula (fig. 891) lies deeply in the floor of the lateral sulcus and is almost surrounded by a *circular sulcus*. It has been hidden and buried by the over-

* G. Elliot Smith, *Journal of Anatomy*, vol. lxiv. 1930.

growth of the cortical areas which adjoin it, and it can only be seen when the lips of the lateral sulcus are widely separated. These areas of the cortex are therefore termed the *opercula of the insula,* and they are separated from each other by the three rami of the lateral sulcus. The *orbital operculum* lies below the anterior horizontal ramus and is formed by the pars orbitalis of the inferior frontal gyrus. The *frontal operculum* lies between the anterior horizontal and ascending rami, and is formed by the pars triangularis of the inferior frontal gyrus. It may be of small size in cases where the two rami between which it lies arise by a common stem. The *frontoparietal operculum* lies between the anterior ascending and the upturned end of the posterior ramus of the lateral sulcus. It is formed by the pars posterior of the inferior frontal gyrus, by the lower ends of the precentral and postcentral gyri, and by the lower end of the anterior part of the inferior parietal lobule. The *temporal operculum* lies

FIG. 890.—A section showing the upper surface of the left temporal lobe.



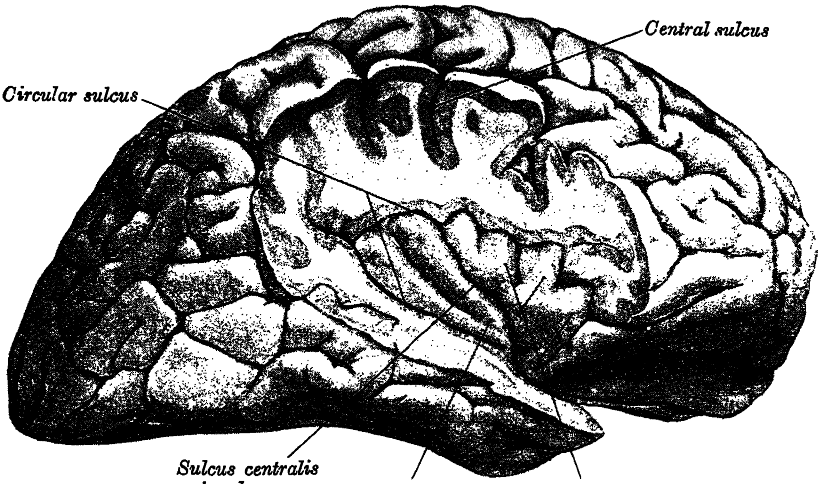
below the posterior ramus and is formed by the superior temporal gyrus and the transverse temporal gyri.

When the opercula have been removed, the insula is seen as a pyramidal eminence, the apex of which is directed towards the anterior perforated substance. In this situation the circular sulcus is deficient and the medial part of the apex is termed the *limen insulæ.* The surface of the insula is divided into a larger anterior and a smaller posterior part by the *sulcus centralis insulæ,* which runs upwards and backwards from the apex of the insula. The anterior part is divided by shallow sulci into three or four *short gyri,* while the posterior part is formed by one long gyrus, which is often divided at its upper end. The cortical grey matter of the insula is continuous with that of the various opercula round the bottom of the circular sulcus. The insula overlies, and is more or less coextensive with the claustrum and the putamen of the lentiform nucleus.

The medial surface of the cerebral hemisphere.—This surface cannot be examined until the two cerebral hemispheres have been separated from each other by the division of (1) the commissures which connect them and (2) the roof, floor, anterior and posterior walls of the third ventricle (fig. 881). The most conspicuous feature on this surface is the great commissure which is termed the *corpus callosum.* It forms a broad arched band which lies in the floor of the central part of the longitudinal fissure. The recurved, anterior end

of the corpus callosum is termed the *genu*. Below, it is continuous with the *rostrum*, which narrows rapidly as it passes backwards to become connected to the upper end of the lamina terminalis ; above, it is continuous with the *trunk*, which a ches upwards and backwards to end in a thickened, rounded extremity, termed the *splenium*. The deep surfaces of the trunk, genu and rostrum give attachment to the laminæ of the septum lucidum, which occupies the interval between them and the fornix—a curved, flattened band of fibres which lies at a lower level. Immediately in front of the lamina terminalis and almost co-extensive with it, there is a narrow, triangular field of grey matter, which is termed the *paraterminal gyrus* (paraterminal body) (p. 986). Anteriorly it is separated from the rest of the cortex by a shallow groove which is named the *posterior parolfactory sulcus*. A little in front of this groove a second, short, vertical sulcus may be present and is termed the *anterior parolfactory sulcus*. The portion of cortex which lies between these two sulci constitutes the *parolfactory area* (fig. 892).

FIG. 891.—The insula of the right side. Exposed by the removal of the opercula.



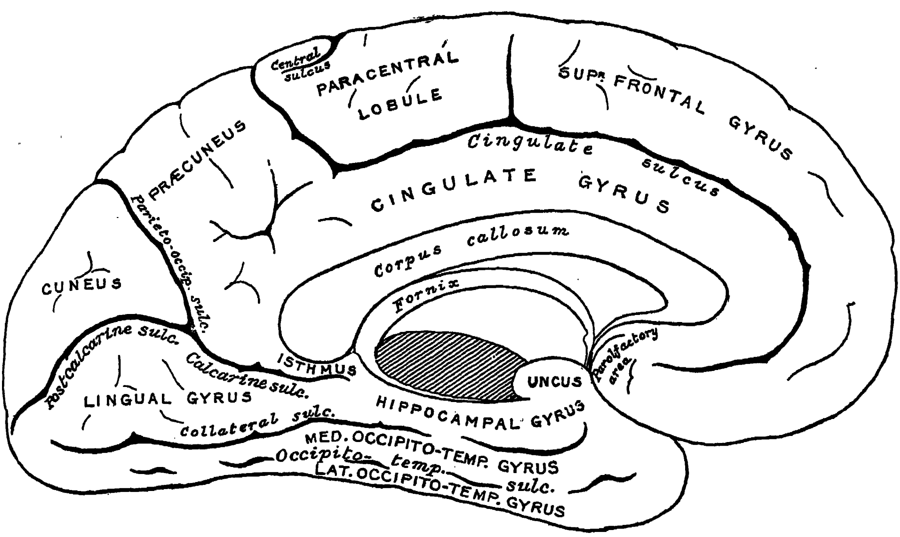
The anterior part of this surface of the hemisphere is divided into an outer and an inner zone by a curved sulcus, termed the *sulcus cinguli*. It commences below the rostrum of the corpus callosum and passes first forwards, then upwards and finally backwards, conforming to the curvature of the corpus callosum. Its posterior end turns upwards to reach the superomedial margin of the hemisphere, about 4 cm. behind the mid-point between the frontal and occipital poles, and lies behind the upper extremity of the central sulcus (fig. 892). The outer zone demarcated by the sulcus cinguli forms a part of the frontal lobe. It is subdivided into a larger anterior portion and a smaller posterior portion by a short fissure which runs upwards from the sulcus cinguli above the middle of the trunk of the corpus callosum. The larger anterior portion is the *medial frontal gyrus*, while the smaller posterior portion is termed the *paracentral lobule*. The upper end of the central sulcus usually cuts into the posterior part of the paracentral lobule and the motor cortex of the precentral gyrus is directly continuous with the cortex of the lobule. This area contains the centres which control the movements of the lower limb and perineal region of the opposite side.

The inner zone which is marked off by the sulcus cinguli constitutes the *gyrus cinguli*. Commencing below the rostrum this gyrus follows the curve of the corpus callosum, from which it is separated by the *callosal sulcus*, and it continues round the splenium on to the inferior surface of the hemisphere to become continuous with the hippocampal gyrus. It is connected with the anterior nucleus of the thalamus both by afferent and by efferent pathways.

The line of the sulcus cinguli is interrupted behind the paracentral lobule, but is partially continued by a short sulcus, of variable form, termed the *suprasplenial sulcus* (subparietal sulcus).

The posterior part of the medial surface of the hemisphere is marked by two deep sulci which converge anteriorly and meet a short distance behind the splenium of the corpus callosum. These are the parieto-occipital and the postcalcarine sulci. The *parieto-occipital sulcus* commences on the superomedial margin of the hemisphere about 5 cm. in front of the occipital pole and is directed downwards and slightly forwards to meet the postcalcarine sulcus. When the lips of the sulcus are widely separated it will be found that, although on the surface of the hemisphere the parieto-occipital and the postcalcarine sulci are apparently continuous, they are in reality separated from each other by a buried gyrus, termed the *gyrus cunei*. In addition, the walls of the sulcus show the presence of two or more vertically disposed sulci. These sulci

FIG. 892.—The medial surface of the left cerebral hemisphere.

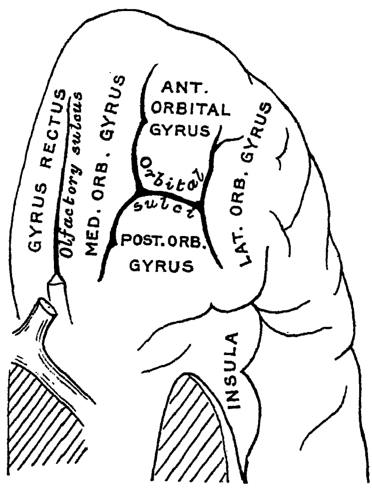


were originally exposed on the medial surface of the hemisphere, but they became buried and included in the parieto-occipital sulcus owing to the growth of the splenium of the corpus callosum (p. 975). The walls of the parieto-occipital sulcus, therefore, resemble the walls of the lateral sulcus, although the contained sulci and gyri are fewer in number and smaller in extent.

The *postcalcarine sulcus* commences in the neighbourhood of the occipital pole. Although the sulcus is usually restricted to the medial surface of the hemisphere its posterior end occasionally extends on to the lateral surface. It runs forwards a little above the inferomedial margin of the hemisphere, taking a slightly curved course with an upward convexity, and joins the parieto-occipital sulcus at an acute angle a little behind the splenium of the corpus callosum. At that point the postcalcarine sulcus is, superficially, directly continuous with the *calcarine sulcus*, but the floor of the sulcus is crossed by the buried anterior cuneolingual gyrus, which separates the two sulci from each other. The calcarine sulcus crosses the inferomedial margin and gains the inferior aspect of the hemisphere, where it cuts into the gyrus cinguli, leaving it connected to the hippocampal gyrus only by a narrow *isthmus*. The postcalcarine sulcus develops as an axial sulcus, set in the long axis of the visual cortex. The calcarine sulcus, however, is a limiting sulcus, and separates the striate, visual cortex from the cortex of the gyrus cinguli. It conforms to the definition of a true sulcus, since it produces an elevation in the medial wall of the posterior horn of the lateral ventricle (the calcar avis).

The quadrilateral area, bounded in front by the upturned end of the sulcus cinguli, behind by the parieto-occipital sulcus, above by the superomedial margin and below by the suprasplenial (subparietal) sulcus, is termed the *precuneus* and, together with the part of the paracentral lobule which lies behind the central sulcus, constitutes the medial surface of the parietal lobe.

FIG. 893.—The orbital surface of the left frontal lobe.



The wedge-shaped area bounded in front by the parieto-occipital sulcus, below by the postcalcarine sulcus and above by the superomedial margin, is termed the *cuneus*. Its surface is usually indented by one or two small irregular sulci, and forms the medial surface of the occipital lobe.

The inferior surface of the cerebral hemisphere.—This surface is subdivided into a smaller, anterior portion, which lies in front of the stem of the lateral fissure, and a larger, posterior portion, which lies behind it. The anterior portion forms the *orbital surface of the cerebral hemisphere.* It is concave from side to side and rests on the cribriform plate of the ethmoid bone and on the orbital plate of the frontal bone. An anteroposterior sulcus traverses this surface near its medial margin and, since it is hidden by the overlying olfactory bulb and tract, it is termed the *olfactory sulcus*. The medial strip of cortex which it marks off is the *gyrus rectus*. The rest of this surface is divided by an H-shaped *orbital sulcus* into four gyri. These are named the anterior, medial, posterior and lateral orbital gyri according to their positions. The last-named is continuous round the superciliary margin with the inferior frontal gyrus.

The posterior portion forms the *tentorial surface* of the hemisphere, and rests partly on the tentorium cerebelli and partly on the floor of the middle cranial fossa. It is traversed by two anteroposterior sulci, the collateral and the occipitotemporal (inferior temporal). The *collateral sulcus* commences near the occipital pole and runs forwards, roughly parallel to the calcarine sulcus, from which it is separated by the *lingual gyrus*. Anteriorly the collateral sulcus may be continued into the *rhinal sulcus*, but the two are usually separated. The *rhinal sulcus* runs forwards in the line of the collateral sulcus and separates the temporal pole from a somewhat hook-shaped elevation which lies posteromedial to it and is termed the *uncus*. This fissure marks the lateral limit of the piriform area of the cortex (p. 985).

The *occipitotemporal* (inferior temporal) *sulcus* lies roughly parallel to the collateral sulcus and on its lateral side. As a rule it does not extend as far back as the occipital pole, and it is frequently divided into two or more parts.

The *lingual gyrus* lies between the calcarine and the collateral sulci. Anteriorly it passes without interruption into the *hippocampal gyrus*, which commences at the *isthmus*, where it is directly continuous with the gyrus cinguli, and passes forwards bounded on its lateral side by the collateral and rhinal sulci. Anteriorly it becomes continuous with the uncus, and as it passes forwards its medial edge abuts on the side of the mid-brain. The *uncus* is the recurved, hook-like, anterior end of the hippocampal gyrus and forms the posterolateral boundary of the anterior perforated substance. The medial part of its hook extends laterally above its lateral part and will be described later (p. 985); its inferior surface cannot be exposed completely until the lateral and more superficial part of the hook has been removed (fig. 895). The uncus forms the bulk of the *piriform area*, which constitutes an important part of the rhinencephalon and is phylogenetically one of the oldest parts of the pallium. It is believed that the higher centres for the sense of taste are situated in the hippocampal gyrus, in the neighbourhood of the uncus.

The *medial occipitotemporal* (fusiform) *gyrus* extends from the neighbourhood of the occipital to the temporal pole. It is limited by the collateral and rhinal sulci on its medial side and by the occipitotemporal sulcus on its lateral side. The lateral part of this area forms the *lateral occipitotemporal gyrus*, which is continuous round the inferolateral margin of the hemisphere with the inferior temporal gyrus.

The Rhinencephalon

The rhinencephalon includes all those portions of the cerebrum which are concerned with the reception and conduction of olfactory impressions. In lower vertebrates the rhinencephalon consists of the olfactory lobe and the archipallium, and includes nearly the whole of the fore-brain. In man, however, the archipallium has been so much reduced by the exuberant growth of the neopallium that many of its derivatives are difficult to recognise with the naked eye. They have been relegated to the medial and inferior surfaces; some have become thinned out into a fine sheet by the growth of the corpus callosum (p. 999), while others have been overgrown and buried by the development of neighbouring neopallial areas.

The constituent parts of the rhinencephalon are: (1) the *olfactory bulb*, in which the primary olfactory neurones end and the secondary neurones begin, (2) the *olfactory tract*, which conveys the secondary olfactory neurones to (3) the *olfactory pyramid*, the *olfactory tubercle*, the *anterior perforated substance* and the *area piriformis*, which give rise to the tertiary olfactory neurones, (4) the *hippocampal formation*, in which the tertiary neurones end, (5) the *paraterminal gyrus*, (6) the *fornix*, which constitutes the efferent pathway from the hippocampal formation and the archipallium in general, and (7) the *nucleus habenulæ*. Some writers include the septum lucidum in the rhinencephalon, but until the details of its development and its morphology are more fully known, it may, perhaps, more justly be considered together with the cerebral commissures to which it owes its existence.

(1) The **olfactory bulb** (see also p. 995) is an oval, reddish-grey mass which lies above the medial edge of the orbital plate of the frontal bone and below the anterior end of the olfactory sulcus on the orbital surface of the frontal lobe. The olfactory nerves pass upwards through the cribriform plate from the olfactory region of the nasal mucous membrane and enter its inferior surface.

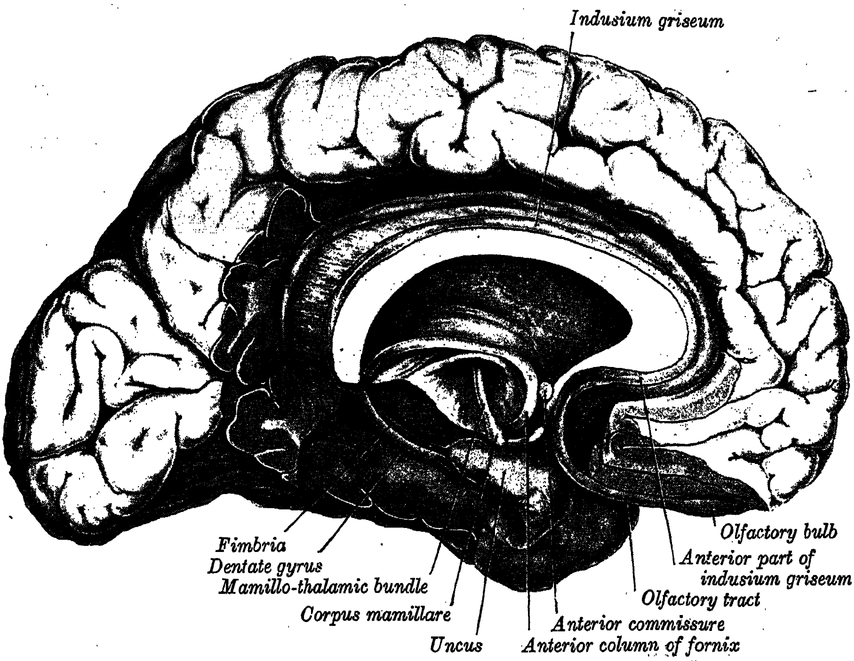
(2) The **olfactory tract** is a narrow, white band which issues from the posterior end of the olfactory bulb and passes backwards on the orbital surface of the frontal lobe, covering the olfactory sulcus. On transverse section it is triangular in outline, the apex being directed upwards. At its somewhat expanded posterior end, which is termed the *olfactory peduncle*, the tract is inserted into the cerebrum. The constituent fibres diverge from one another, forming the lateral and medial roots of the olfactory tract, and enclosing the *olfactory pyramid*. The *lateral root* passes laterally at first in the anterior part of the anterior perforated substance, where its fibres can usually be detected with the naked eye. They are associated with a narrow band of grey matter derived from the piriform area but indistinguishable from the grey matter of the anterior perforated substance. On reaching the limen insulæ (p. 980) the lateral root and its accompanying grey matter bend sharply backwards and medially in the floor of the stem of the lateral sulcus and enter the superolateral part of the uncus. The *medial root of the olfactory tract* turns medially and ascends on the medial aspect of the hemisphere in the posterior part of the parolfactory area and immediately in front of the paraterminal gyrus, which separates it from the upper end of the lamina terminalis. Like the lateral root, it is associated with a strip of grey matter. The primary connexions of the medial root in the human brain are uncertain, but it is probable that the secondary connexions pass to the indusium griseum (p. 999) on the inferior surface of the rostrum of the corpus callosum (fig. 894).

(3) (*a*) The *olfactory pyramid* is a small area of grey matter situated between the diverging roots of the olfactory tract and in front of, and in surface continuity with, the anterior perforated substance.

(*b*) The *olfactory tubercle* lies immediately posterolateral to the olfactory pyramid. Very rarely it is visible in the human brain as a small oval elevation in the anterior perforated substance.

(*c*) The **anterior perforated substance** lies on the basal surface of the cerebral hemisphere in the angle between the optic tract and the uncus. In front it is bounded by the olfactory tubercle and the roots of the olfactory tract. Medially it is continuous, above the optic tract, with the tuber cinereum and, in front of that, with the lower end of the paraterminal gyrus. Laterally it extends to the limen insulæ (p. 980). Its exposed surface is pierced by the central branches of the anterior and middle cerebral arteries and is crossed by the latter vessel. Superiorly it is continuous with the grey matter of the corpus striatum and of the claustrum, and it is separated from the anterior part of

FIG. 894.—A dissection of the left cerebral hemisphere, showing the parts of the rhinencephalon. Drawn from a specimen lent by Professor R. B. Green.



the globus pallidus of the lentiform nucleus by the anterior commissure, the ansa lenticularis and the ansa peduncularis.

(*d*) The **piriform area** includes the anterior part of the *hippocampal gyrus*, the *uncus* and the band of grey matter which reaches it along with the lateral root of the olfactory tract. When the lateral part of the uncus is removed, the inferior surface of its medial part can be examined. It is crossed about its middle by a narrow band of grey matter, continuous at its lateral end with the dentate gyrus, and termed the *tail of the dentate gyrus* (banderella of Giacomini) (fig. 895). The portion of the uncus which lies behind the tail of the dentate gyrus has been termed the *intralimbic gyrus* (hippocampus inversus, of Elliot Smith), and it is morphologically distinct from the part lying anterior to it, which has the histological characters of the piriform cortex (p. 996).

The tertiary olfactory neurones, which arise in the olfactory tubercle and pyramid and in the piriform area, proceed at once into the hippocampal formation, but they do not form any composite tract.

(4) The **hippocampal formation** is formed along the fringe of the pallium on the medial aspect of the hemisphere. It comprises (*a*) the *indusium griseum*, (*b*) the *longitudinal striæ* of the corpus callosum, (*c*) the *dentate gyrus*, and (*d*) the *hippocampus*.

The hippocampal formation is laid down in the embryo on the medial wall of the hemisphere, forming an arch immediately outside the arch of the choroidal

fissure (p. 118). The anterior or upper part of the arch is invaded by the corpus callosum, and the great size of this structure in the human brain reduces the corresponding portion of the hippocampal formation to the mere vestige which is represented by the indusium griseum on the surface of the corpus callosum (fig. 894) and the associated longitudinal striæ. The posterior or lower part of the arch is carried downwards and forwards by the growth of the temporal lobe and so is not affected by the development of the corpus callosum. The *hippocampal sulcus* develops in this part of the hippocampal formation, outside the choroidal fissure, and the strip of cortex which lies between the two forms the dentate gyrus. The cortex at the bottom of the sulcus proliferates rapidly and bulges laterally into the cavity of the inferior horn of the ventricle, constituting the hippocampus.

(*a*) The *indusium griseum* is the thin sheet of grey matter which covers the upper surface of the corpus callosum and is continuous on each side, round the bottom of the callosal sulcus, with the cortex of the gyrus cinguli. It is continuous behind with the *splenial gyrus*, a delicate layer of grey matter which is in continuity with the posterior end of the dentate gyrus (fig. 903). In front it is continued round the genu and on to the inferior surface of the rostrum of the corpus callosum, to become continuous with the parolfactory area and the paraterminal gyrus.

(*b*) The *medial* and *lateral longitudinal striæ* are two ridges which extend forwards on the upper surface of the corpus callosum. The medial stria lies close to the median plane, but the lateral stria is placed under cover of the gyrus cinguli in the floor of the callosal sulcus. They consist of longitudinally running fibres, which sweep round the genu and over the rostrum to enter the paraterminal gyrus (*vide infra*). They represent the white substance of the vestigial indusium griseum.

(*c*) The *dentate gyrus* is a narrow, crenated strip of cortex which lies on the *upper* surface of the hippocampal gyrus, under cover of the fimbria (fig. 895), from which it is separated by the fimbriodentate sulcus. The *hippocampal sulcus* intervenes between it and the hippocampal gyrus, but except at its anterior end this sulcus is not constantly present in the adult human brain. Posteriorly the dentate gyrus is prolonged on to the under-surface of the splenium of the corpus callosum, as the delicate *splenial gyrus* (fig. 903), which in turn becomes continuous with the indusium griseum. Anteriorly the dentate gyrus is continued into the notch of the uncus, and then bends sharply medially across its inferior surface (fig. 895). This transverse portion is termed the *tail of the dentate gyrus*. Unlike the rest of the gyrus it is smooth and featureless, and it becomes lost on the medial aspect of the uncus.

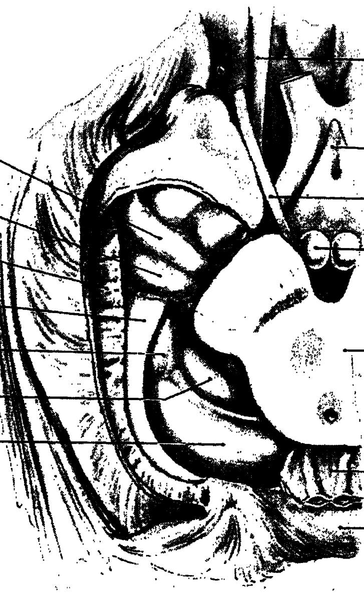
(*d*) The *hippocampus* is a curved elevation, about 5 cm. long, which extends throughout the entire length of the floor of the inferior horn of the lateral ventricle (fig. 910). Its anterior or lower extremity is enlarged and presents two or three shallow grooves separated by digit-like ridges, which give it a paw-like appearance. On this account it is termed the *pes hippocampi*. The elevation itself is usually described as being produced by the hippocampal sulcus, but Elliot Smith maintains that this is not actually the case, and that the elevation owes its presence to the rapid proliferation of the cells of the hippocampal formation in this situation. The ventricular surface of the hippocampus is covered by a layer of white fibres which constitutes the *alveus*, but the great bulk of the elevation is made up of grey matter. Posteriorly the hippocampus, like the dentate gyrus, becomes continuous with the splenial gyrus at the splenium of the corpus callosum.

(5) The *paraterminal gyrus* (subcallosal gyrus of Zuckerkandl) is the triangular area of the cortex which lies immediately in front of the lamina terminalis (fig. 881). Anteriorly it is limited by the posterior parolfactory sulcus, and superiorly it becomes continuous with the indusium griseum on the inferior surface of the rostrum of the corpus callosum. Inferiorly it is connected to the piriform area by a white band, termed the *diagonal band*, which runs laterally and backwards across the posterior part of the anterior perforated substance (fig. 876). The significance of the paraterminal gyrus in the rhinencephalon has not yet been definitely determined.

(6) The **fornix** is the efferent pathway from the cells of the hippocampal

formation, and therefore conveys olfactory fibres of the fourth neurones. The fibres of the cells of the hippocampus pass to its ventricular surface where they form a layer of white matter, termed the *alveus*. The fibres of the alveus converge on the medial border of the hippocampus to form the *fimbria*, a flattened band of white fibres which lies above the dentate gyrus and immediately below the lower part of the choroidal fissure. The disposition of the fimbria is variable. It may project above the dentate gyrus, with a free medial edge and a lateral border which merges into the alveus, or its free border may be twisted over towards the lateral side, uncovering the dentate gyrus (fig. 903). Anteriorly, the fimbria passes into the hook of the uncus (fig. 895). Traced backwards on the floor of the inferior horn of the ventricle, it ascends below the splenium and bends forwards above the thalamus, forming the *posterior column of the fornix*. The two posterior columns are closely applied to the under surface of the corpus callosum and are connected to each other by a number of transverse fibres which pass between the hippocampal formations

FIG. 895.—A dissection of the inferior surface of the brain to display the uncus, the dentate gyrus and the fimbria.



of the two hemispheres and form the *hippocampal commissure*. This commissure presents the appearance of a thin, triangular lamina. Between it and the corpus callosum a horizontal cleft (the so-called *ventricle of the fornix* or *ventricle of Verga*) is sometimes found.

Anteriorly the two posterior columns come together in the median plane and constitute the *body of the fornix*, which is really a symmetrically disposed bilateral structure. The body of the fornix lies above the tela chorioidea and the ependymal roof of the third ventricle (fig. 885) and is attached above to the under surface of the corpus callosum and, more anteriorly, to the lower borders of the laminæ of the septum lucidum. Laterally the body of the fornix overlies the medial part of the upper surface of the thalamus (p. 955) and the choroidal fissure is placed below its free, lateral edge. Through this fissure the choroid plexus in the lateral margin of the tela chorioidea thrusts its way into the body of the lateral ventricle (fig. 885).

Above the interventricular foramen the body of the fornix separates into two *anterior columns*, which bend downwards and backwards, forming the anterior boundary of the interventricular foramen and passing behind the anterior commissure. As they descend, each sinks into the anterior part of the corresponding lateral wall of the third ventricle and reaches the corpus mamillare,

in which it terminates (p. 963). Some of the fibres of the fornix system leave the column near the interventricular foramen and run backwards, as the stria habenularis (p. 961), to reach the nucleus habenulæ of the same or the opposite side. A slender bundle of fibres, named the *olfactory fasciculus*, leaves the anterior column of the fornix and descends in front of the anterior commissure to the base of the brain where it divides into two parts ; one joins the medial root of the olfactory tract ; the other joins the indusium griseum of the corpus callosum and through it reaches the hippocampal gyrus.

The fornix is the efferent pathway for the archipallium, and its fibres, relayed in the corpora mamillaria, pass to the anterior nucleus of the thalamus by the mamillothalamic tract and to the tegmentum of the brain-stem by the mamillotegmental tract (p. 963).

(7) The *nucleus habenulæ* and its afferent and efferent fibres have already been described (p. 961).

THE STRUCTURE OF THE CEREBRAL CORTEX

The nerve-cells of the cerebral cortex show a wide variation in size and shape, and in the mode of behaviour of their dendrites and axons. In all parts of the cortex they are laid down in strata, but the transition from stratum to stratum is not sharp and clear-cut, and, as a result, different observers have adopted different descriptions of the stratification. It must be remembered that many fibres reach the cortex from the underlying white matter and run, for the most part, at right angles to the surface, breaking up the cellular constituents into parallel columns. Others, however, alter direction after penetrating the cortex and, together with intracortical fibres, form two sheets —or in some situations three—which lie parallel to the surface. The most superficial layer of the cortex consists of fibres which run tangentially ; amongst them there are many neuroglial cells, the horizontal cells of Cajal and cells of Golgi, type II. In the substance of the cortex there may be two sheets of fibres parallel to those in the superficial or molecular layer. They appear in sections of the cortex as narrow bands, termed the outer and inner bands of Baillarger ; they vary in thickness in different cortical areas. In the visuosensory cortex, the outer band forms a broad strip which can readily be recognised by the naked eye and is termed the *visual stria*. It is so characteristic a feature that the visuosensory area is named the *striate area*. In many regions the inner band of Baillarger is completely obscured and it may be entirely absent.

The depth of the cortex is always greater on the exposed surfaces of the gyri than it is in the depths of the sulci, and varies from 4 mm. in the precentral gyrus to 1·25 mm. in the occipital lobe.

In the human fœtus at the sixth month three layers can be made out in the cortex, viz.—a superficial or *molecular layer*, consisting mainly of tangential fibres, an intermediate or *granular layer* of cells, and a deep or *infragranular layer* of cells. This three-layered arrangement is typical of the archipallium, and is found in the adult human brain in the hippocampal formation. The granular layer constitutes the receiving mechanism, and the infragranular layer the transmitting mechanism. In the later months of fœtal life the neopallium becomes further differentiated. The advent of additional association and commissural afferent fibres leads to a thickening and differentiation of the granular layer. It gives rise to an *outer granular layer*, which merges into a *pyramidal layer* of cells. Deep to the pyramidal layer there is a fourth layer, consisting of small stellate or granular cells, termed the *inner granular layer*. At the same time, the infragranular layer thickens and differentiates into a deeper, *polymorphous layer*, in which small fusiform cells predominate, and a more superficial *ganglionic layer*, in which the cells are more densely packed and giant pyramidal or stellate cells may be found. The growth of the infragranular layer is contemporaneous with the increase in number of the corticofugal and outgoing commissural fibres.

The adult cortex may therefore be considered as subdivided into six different

strata, which differ in the depths of the various layers and in the number and character of their constituent cells in different parts of the hemisphere.

(1) The *molecular layer* consists of a stratum of medullated fibres (plexus of Exner) that run parallel to the surface. It varies in its depth and in the density of the fibres which it contains. In its deeper part it contains the apical dendrites of the pyramidal cells, the axons of the cells of Martinotti, and fibres derived from the subjacent white substance of the hemisphere. In addition, it contains (*a*) small, irregularly-shaped nerve-cells with short axons and a variable number of dendrites, and (*b*) fusiform cells, lying with their long axes parallel to the surface.

(2) The *outer granular layer* is of approximately the same depth as the first layer. The cells are small, averaging 8μ to 10μ in diameter, having disproportionately large nuclei.

(3) The *pyramidal layer* shows a gradual increase in the size of its constituent cells as they are traced inwards from the surface. Its outer part presents few variations throughout the whole extent of the cortex. The constituent cells are typical pyramidal cells, and are more widely separated from one another than the cells in the second layer.

The inner part of the pyramidal layer shows considerable variations in different areas. Its cells have an average diameter of $25\text{-}30\mu$, and they show a marked increase in the number and size of the contained Nissl's granules. The deepest part of this layer is traversed by the outer band of Baillarger.

(4) The *granular layer* forms a narrower stratum, made up of small stellate cells, which vary in their number and in their density in different cortical areas. They average $8\text{-}10\mu$ in diameter; their axons are short and terminate in the same layer or in the pyramidal layer.

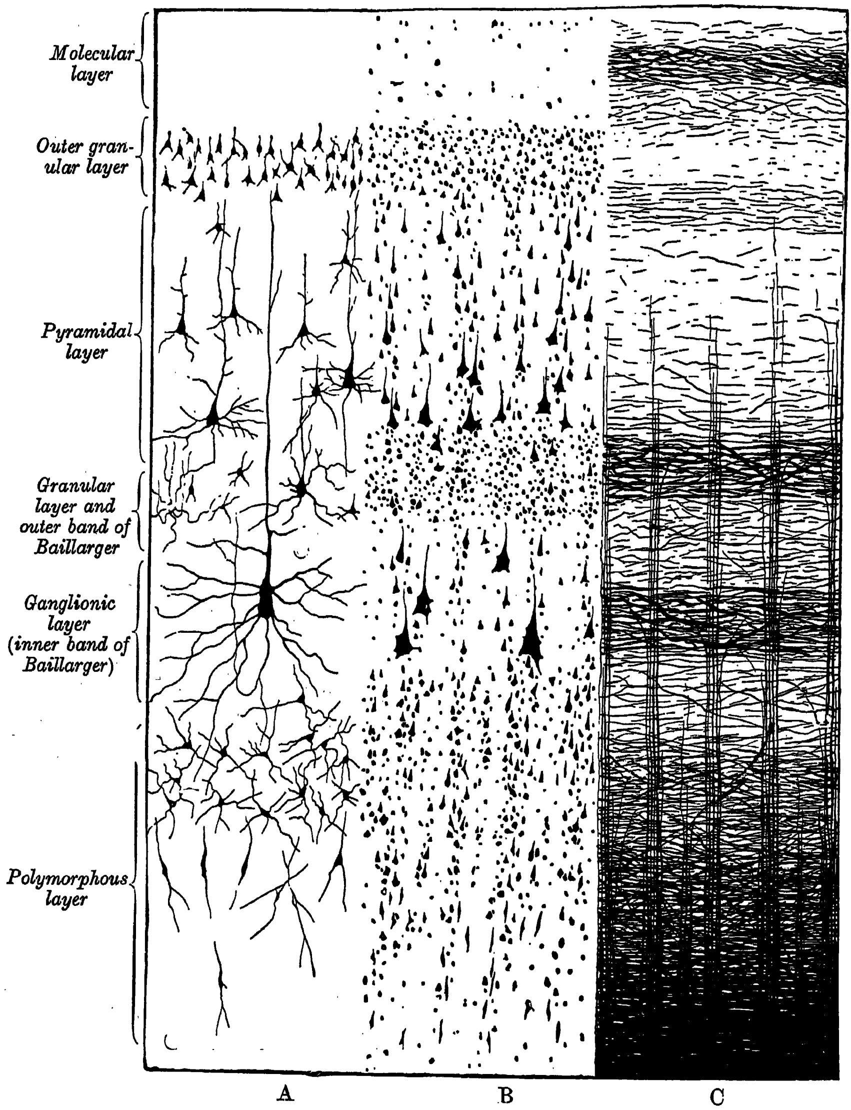
(5) The *ganglionic layer* shows striking differences in different cortical areas. In the motor area the characteristic cells of this stratum are the giant pyramidal cells of Betz, which vary from 35μ by 17μ to 60μ by 25μ (Bevan Lewis), but many smaller cells of varying form are found in the same layer. In other parts of the cortex large cells may be entirely absent, or the large pyramidal cells may be replaced by large stellate cells (visuosensory area, p. 993). In certain situations the inner band of Baillarger is a recognisable feature in this stratum.

(6) The *polymorphous layer* is composed mainly of spindle-shaped or fusiform cells. These are subdivided into columns by sheets of radial fibres which traverse the polymorphous layer on their way to and from the more superficial layers of the cortex. Most of the axons of the polymorphous cells pass into the subjacent white matter, while their dendrites pass towards the surface but do not reach the molecular layer. The cells of Martinotti are found in this layer, as well as in the superposed layers. They are pyramidal in shape, but their bases are directed towards the surface. Their dendrites are short and their axons pass into the molecular layer, where they form an extensive horizontal arborisation. The cells of Martinotti are most numerous in the piriform area. The incoming and outgoing radial fibres vary in density with the fibre wealth of the individual area. They include the efferent axons of the cells of the ganglionic and of the polymorphous layers and the afferent projection, association and commissural fibres together with the axons of the cells of Martinotti. In addition, numerous horizontal fibres intersect the radial fibres. They are derived from (*a*) the branching axons of Golgi cells, type II; (*b*) collaterals of the axons of the large pyramidal and polymorphous cells and of the cells of Martinotti; and (*c*) the collaterals of the incoming fibres.

The cells which constitute the grey matter of the cortex show great variation in their size and shape and in the mode of behaviour of their axons and dendrites. The pyramidal cells, the cells of Martinotti, and the Golgi cells, type II, constitute a very large proportion of the total. (*a*) The pyramidal cells, irrespective of their size and their position, send basal dendrites into the surrounding area, and apical dendrites towards the surface, where they terminate by arborising in the molecular layer. Their axons arise from the base of the cell or from one of the basal dendrites and run centrally into the deeper layers or into the white matter. They give off collaterals, many of which ascend to the more superficial strata. (*b*) The cells of Martinotti may be pyramidal,

ovoid or fusiform in shape. They are characterised by the course of their axons, which ascend to reach the molecular layer and there divide into tangential branches. These cells are found in all the layers of the cortex, but are largest and most numerous in the polymorphous layer. Many of the afferent fibres

FIG. 896.—A diagram showing the layers of cells and fibres in the grey matter of the cortex of the human cerebral hemisphere, according to the histological methods of Golgi, Nissl and Weigert. After Brodmann; from Luciani's *Physiology* (Macmillan & Co., Ltd.).



A. Stained by the method of Golgi. B. by that of Nissl. C. by that of Weigert.

to the cortex terminate by arborising with the dendrites of the cells of Martinotti, and the impulses which they convey are carried by the axons of the same cells to the molecular layer where they establish contact with the dendrites of the pyramidal cells. (*c*) The Golgi cells, type II, vary in size and in position. They are characterised by the shortness of their axons, which never leave the grey substance although they may pass from one layer to another. They establish connexions between cells in the same layer and also between cells in different layers. It is believed that the small cells which form the granular

layers come into synaptic association with the incoming itinerant (projection), commissural and association fibres. They therefore act as the receptors and distributors of afferent impressions to the cortex.

The researches of Bevan Lewis, Bolton, Campbell, Brodmann, Economo and Elliot Smith into cortical structure, the embryological investigations of Flechsig and the experimental work of Sherrington and many others, have shown that the cortex of the cerebral hemispheres can be mapped out into areas which differ from one another in the details of their structure, in the period of the myelination of their efferent fibres and in their functional significance. Economo has mapped out more than 100 different areas as the result of a histological survey of the cortex, and certain of these areas are so important from the functional standpoint that, although the structure of the cortex in general has already been described, further reference must be made to these local variations.

Of the five fundamental types which Economo recognises in the cortical structure of the neopallium, the agranular and the granulous varieties are the most distinctive, as they represent the extremes of the variations which occur. (1) The *agranular type* is marked by the almost complete absence of the granular cells, which are replaced by pyramidal elements. This type of cortex is found in the motor and psychomotor areas. (2) The *granulous type* is marked by the depth and density of the granular layers, by the reduction in the number of the pyramidal elements and by the diminution in the total depth of the cortex. It is found in the strictly sensory areas, viz. the somesthetic, the visuosensory or striate, and the auditosensory areas.*

The **precentral area** includes the precentral gyrus and the posterior portions of the superior, middle and inferior frontal gyri (Campbell). The whole of this area is characterised by the almost complete absence of the granular layer. It is subdivisible into posterior and anterior parts. The posterior part does not reach so far forward as the precentral sulcus, and it is characterised by the giant pyramidal cells of Betz, which are found in the ganglionic layer. These large cells are more numerous in the upper part of the area, and their axons form the great cerebrospinal (pyramidal) motor tract. The whole area shows a great wealth of intracortical fibres, and the molecular layer is unusually dense. Experimental evidence has shown that this area controls the volitional movements of the opposite half of the body, and that the upper end of the precentral gyrus and the adjoining portion of the paracentral lobule control the movements of the lower limb. Below, and in the order given, are found the centres for the trunk, the upper limb, mouth, lips, tongue and larynx.† The largest Betz cells (60μ by 25μ) are found in the lower limb area, and the smallest (35μ by 17μ) in the areas associated with the face and tongue.

Emphasis must be laid on the fact that it is movements and not individual muscles which are represented in the cortex, and in this connexion it may be mentioned that whereas the estimated number of motor cells in the anterior grey column of the spinal cord is between 250,000 and 300,000, the number of Betz cells is estimated at rather less than one-tenth of that figure. It is clear, therefore, that each Betz cell must control the activities of approximately ten anterior column cells.

The anterior part of the precentral area resembles the posterior part in every respect, except for the absence of the giant cells of Betz. The two areas stand in very intimate relationship to each other from the functional standpoint, but the precise relationship is by no means easy to define. Some idea may be conveyed by the statement that, whereas the posterior part of the precentral area is responsible for individual movements, the anterior part is responsible for the control of the orderly series of movements which constitute acts. The young child experiences no difficulty in carrying out individual movements, but he has to learn by repeated efforts how to carry out even the simplest acts such as putting on or buttoning a coat. Every act is a complicated series of movements which must be carried out in their proper order and to their proper extent, and forms a sort of pattern which is capable of registration.

* C. von Economo, *The Cytoarchitectonics of the Human Cerebral Cortex*. Oxford University Press. 1929.

† Immediately in front of the upper limb area, there is an area for the control of the movements of the head and conjugate movements of the eyes.

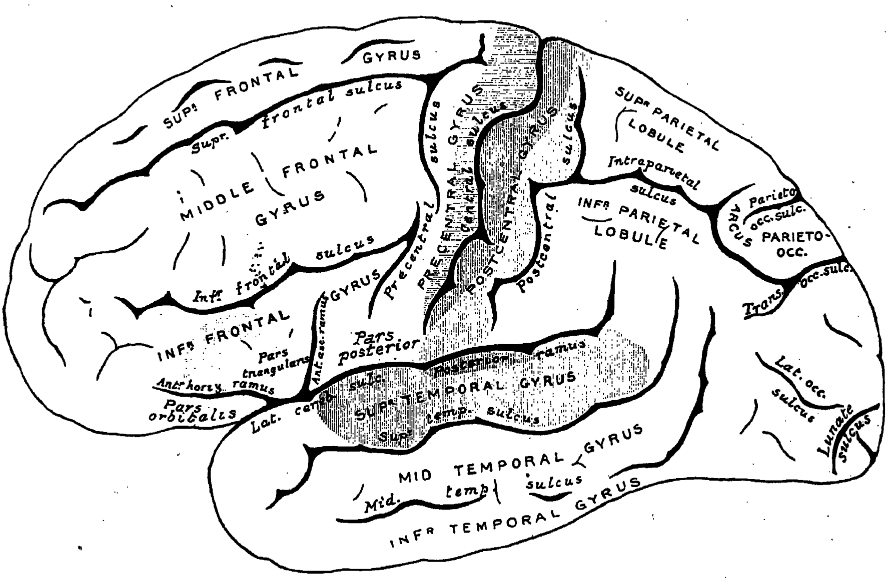
All skilled acts must be learned, and their mastery means that their pattern has been impressed on the cortical cells in the anterior part of the precentral area.

The condition of *apraxia*, which is normal in the young child, is met with in later life as a pathological condition, indicating a cortical or subcortical lesion in the neighbourhood of the area under consideration. Such patients are able to carry out individual movements without difficulty, but they cannot perform a simple act such as lighting a pipe.

These two areas are frequently referred to as the *motor* and the *psychomotor areas*.

The frontal area, which is one of the important association areas of the brain, extends from the psychomotor region to the frontal pole and includes those portions of the frontal lobe which appear on the medial and orbital

FIG. 897.—The areas of localisation on the lateral surface of the left cerebral hemisphere.



Motor area in red. Area of general sensations in blue. Auditory area in green. Visual area in yellow The psychic portions are in lighter tints.

surfaces. It has been subdivided into frontal and prefrontal areas, but in the present state of knowledge of the functions of this wide area little advantage is to be derived from this subdivision.

Histologically this area differs from the adjoining precentral area in the reappearance of the granular layer and in the dimunition of the number of intracortical fibres. The ganglionic layer shows a corresponding reduction in the size and number of its constituent cells. Further, the polymorphous layer is considerably reduced in depth.

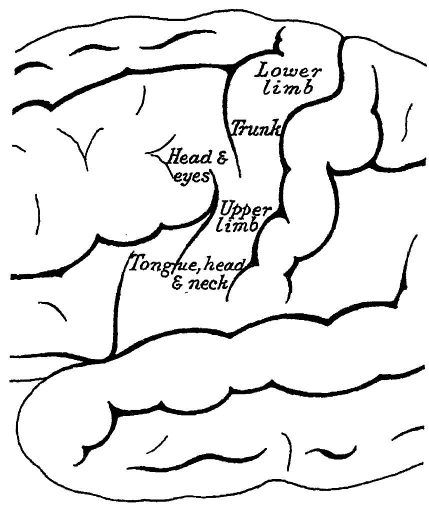
The functions of the frontal area are difficult to analyse and define and, because of the absence of gross symptoms following injury and disease, it was long known as the *silent area* of the brain.

In view of the fact that the frontal area is connected to the somesthetic, visual, auditory and other sensory areas by association fibres and to the thalamus by itinerant fibres, it has been urged that this silent area of the brain analyses the afferent impressions which come to it into those which arouse feelings of pleasure and well-being and those which are unpleasant or distasteful. It determines the personal reaction of the individual according to the alterations in feeling tone, modified or intensified, as the case may be, by the effects of past experience, and it is therefore responsible, in a general way, for behaviour and conduct. It is also concerned with attention and the

power of concentration. This view receives considerable support from clinical evidence. Lesions of the frontal area, whether cortical or subcortical, commonly result in some alterations in the character of the patient—alterations which may be so slight as to be recognised only by his intimates, or may be so gross as to be obvious to any observer.

The **postcentral area** occupies all but the lowest part of the postcentral gyrus and is continued over the supero-medial border into the adjoining part of the paracentral lobule. It is divisible into anterior and posterior parts, which show certain differences in structure and play related though distinct parts in the reception and appreciation of somesthetic impressions. The anterior part is characterised by the number of characteristic cells in the pyramidal layer, by the density of the granular layers and by the breadth of the outer band of Baillarger. The largest cells are found in the ganglionic layer, but they are smaller than the giant cells of Betz and they occur discretely instead of in small clusters. In the posterior part the large pyramidal cells are reduced both in size and number, and the inner granular layer, though rather wider, is not so densely packed with cells.

FIG. 898.—The different parts of the motor area of cerebral cortex.



The postcentral area receives afferent fibres from the thalamus which represent the relays of the somesthetic fibres of the spinal cord and brain-stem. Both exteroceptive and proprioceptive sensations stream into the postcentral area and receive their full recognition in consciousness. The anterior part of the area may be regarded as the actual receiving area for all varieties of somesthetic sensibility, and the posterior part of the area relates them with past experience and so renders possible their evaluation and discrimination. It is therefore responsible for the tactile element in sterognosis, i.e. the recognition of texture, in its widest sense, without the aid of vision.

The **visual area** of the cortex includes the greater part of the occipital lobe, and is subdivided into the *visuosensory* or *striate area* and the *visuopsychic area.*

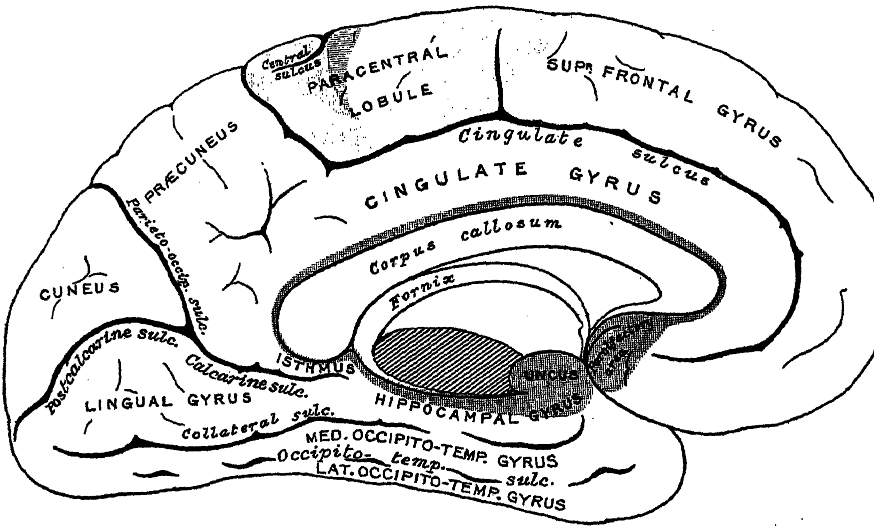
The **visuosensory area** occupies the walls of the postcalcarine sulcus and extends on to the surface of the cuneus above and the lingual gyrus below. Posteriorly it may not extend beyond the occipital pole ; when it does extend on to the lateral surface it is limited by the lunate sulcus in front, and by the polar sulci above and below. Anteriorly the visuosensory area occupies the floor of the calcarine sulcus and the adjoining part of the lingual gyrus. The whole of this area is characterised by the conspicuous *visual stria*, which is quite obvious to the naked eye, and by the shallowness of the cortex. Over the anterior part of the area the stria is broad and a darker strip lies on its inner side. In the polar region and on the lateral aspect of the hemisphere, the stria becomes narrower and the accompanying dark band disappears. This change in the character of the stria corresponds to a difference in the retinal relationships of the striate area (*vide infra*). Histologically the visuosensory area presents four distinguishing features. (1) The deeper part of the pyramidal layer contains a few large stellate cells which almost entirely replace the large pyramidal cells normally found in this position. They are horizontally placed and are regarded by Cajal as specific visual cells. (2) The outer band of Baillarger is broad and conspicuous, constituting the *visual stria* (Gennari). (3) The ganglionic layer contains the solitary cells of Meynert. These are pyramidal in shape, measuring about 30μ, and are arranged in a single, widely spaced, row. (4) The outer and, more especially, the inner granular layers are very conspicuous and the small cells which they contain are closely packed together. The

enormous number of these diminutive elements is a characteristic feature and will be appreciated more fully when it is stated that the striate area contains approximately one-tenth of the total number of the cells in the cerebral cortex. The inner granular layer appears to be duplicated.

The visuosensory area is the cortical receiving centre for visual impressions. Colour, size, form, motion, illumination and transparency are all recognised and appreciated in this area. The recognition and identification of objects, however, requires the co-operation of the adjoining visuopsychic area.

Owing to the partial decussation of the fibres of the optic nerve (p. 967), the visuosensory cortex of one hemisphere receives its impressions from the temporal part of the retina of the same side and from the nasal part of the retina of the opposite side. The upper lip of the postcalcarine sulcus is associated with the upper quadrants indicated, and the lower lip with the lower quadrants (fig. 883). The area for the macula occupies the polar region, extending backwards to the

Fig. 899.—The areas of localisation on the medial surface of the left cerebral hemisphere.



Motor area in red. Area of general sensations in blue. Visual area in yellow. Olfactory area in purple. The psychic portions are in lighter tints.

lunate, upwards to the superior polar and downwards to the inferior polar sulcus. Elliot Smith * estimates that the macular cortical area is as extensive as the whole peripheral retinal area.

The visuopsychic area surrounds the visuosensory area except in its anterior part. In this situation it is restricted to the adjoining lingual and medial occipitotemporal (fusiform) gyri (fig. 899), and does not extend above the calcarine sulcus. The cortex of this area is rather shallower than the cortex of the visuosensory area and is characterised by the breadth of the outer band of Baillarger, which is just as broad as it is in the visuosensory area, though its edges are not quite so sharp. Histologically this area is marked by the number and size of the cells in the deeper part of the pyramidal layer, and by the almost complete absence of large cells from the ganglionic layer.

This area is responsible for the correlation of visual impressions and their association with past experience, leading to the identification and recognition of objects. The determination of distance and the proper orientation of objects in space is effected by the visuopsychic area.

The parietal area is situated between the visual area behind and the post-central area in front, and constitutes one of the large association areas of the hemisphere. Histologically this area is characterised by the absence of large

* *Journal of Anatomy*, vol. lxiv. 1930.

elements from the ganglionic and pyramidal layers and by the breadth of the inner band of Baillarger. The outer and inner granular layers are well developed.

Owing to its position relative to the visual, somesthetic and auditory areas, the parietal area is advantageously situated for the purpose of correlating items of information obtained from these sensory centres. It is through the activities of this part of the brain that accurate knowledge of objects and their significance is obtained and retained. The connexion of the middle part of the inferior parietal lobule (angular gyrus) with the pulvinar (p. 958) has suggested the possibility that it is responsible for the visual element in stereognosis, i.e. it enables tactile impressions to be associated with former visual impressions so that the size and shape of an object can be determined by touch alone and unaided by vision. The associations between the three great sensory areas are so many and complicated that they have defied complete analysis. Reading, for example, demands the association of visual and auditory impressions if it is to convey any intelligent meaning, and the playing of musical instruments requires the association of tactile and auditory impressions.

The **auditory area** of the cortex is associated with the superior temporal gyrus and the transverse temporal gyri. Like the visual area, it can be subdivided into a sensory and a psychic part, the latter adjoining and to a large extent surrounding the former.

The *auditosensory area* occupies the anterior transverse temporal gyrus, which lies in the floor of the posterior ramus of the lateral sulcus (fig. 890), and extends for a short distance and over a limited area on to the lateral surface of the superior temporal gyrus. Histologically this area of the cortex is characterised by the arrangement of its cells in columns set at right angles to the surface, by the thickness of the outer and inner granular layers, and by the great number of fibres which are found throughout its whole depth.

Afferent fibres reach the auditosensory area from the medial geniculate body. After traversing the posterior limb of the internal capsule, these fibres sweep below the posterior part of the lentiform nucleus and form the *auditory radiation*.

In the auditosensory area auditory impressions reach consciousness as sounds, and their loudness, quality and pitch can be differentiated. The direction from which the sound comes and its character, whether rhythmical or arrhythmical, are also determined by this part of the cortex. The significance and the source of the sound, however, require the adjoining auditopsychic area for their elucidation.

The *auditopsychic area* occupies the whole of the remainder of the superior temporal gyrus. Histologically it resembles the auditosensory cortex, but the granular layers are shallower and the pyramidal layer is deeper. In this area auditory impressions receive their interpretation and can be differentiated from one another, as regards their probable source and origin, by association with past experience.

The large *temporal area*, which includes the whole of the middle and inferior temporal gyri, is very similar to the auditopsychic area in its cortical structure. Lesions of this area are accompanied by a more or less marked disturbance of the auditopsychic functions, but it must be confessed that our knowledge of the functional significance of this large part of the cortex is very meagre.

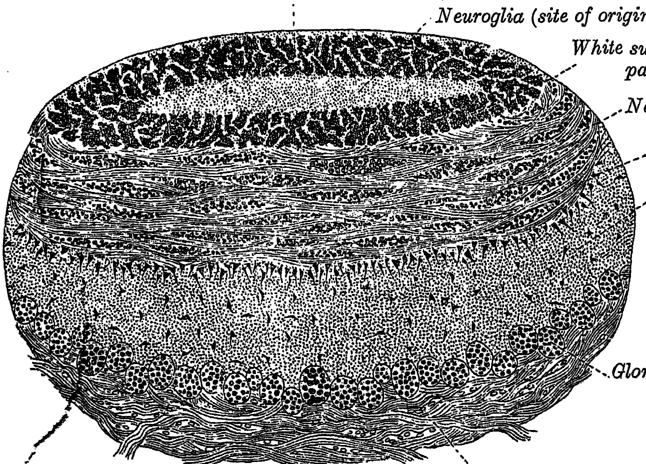
The **insular area** comprises the whole of the insula. Histologically two types of cortex are recognisable. The structure of the cortex of the long gyri show many points of resemblance to that of the temporal area, whereas the cortex of the short gyri is more closely allied to the cortex of the hippocampal gyrus. The functions of this cortical area are unknown.

The structure of the rhinencephalon.—The laminated arrangement which is characteristic of the cerebral cortex is considerably modified in the rhinencephalon. It is found in a different form in the olfactory bulb, but it is almost unrecognisable in the indusium griseum of the corpus callosum, and it is archaic in type in the dentate gyrus and the hippocampus.

The olfactory bulb.—In many animals the olfactory bulb contains a cavity which communicates with the lateral ventricle through a hollow olfactory tract. In man the walls of the bulb become thickened, the ventral wall more so than the dorsal wall, and the cavity is obliterated, and its site is occupied

by a mass of neuroglia. A section through the bulb demonstrates the presence of stratification, and the following layers can be identified: (1) a layer of *olfactory nerve-fibres*.—These fibres are the nonmedullated axons of the olfactory cells in the nasal mucosa, and they reach the bulb by passing through the cribriform plate of the ethmoid bone. They cover the inferior surface of the bulb and penetrate it to end by forming tuft-like synapses with the dendrites of its mitral cells. (2) *Glomerular layer*.—This layer contains numerous spheroidal bodies, termed glomeruli, formed by the branching and interlacement of one or more olfactory nerve-fibres with the descending dendrite of a mitral cell. (3) The *molecular layer*.—This layer consists of a matrix of neuroglia, in which the large, mitral cells form a densely packed stratum. These cells are pyramidal in shape, and from the basal part of each there arises a stout dendrite which descends into the glomerular layer and ends in one of the glomeruli. In addition, the mitral cells give off dendrites which terminate in the molecular layer. Their axons arise from the apices of the cells and proceed upwards into the next layer where they turn backwards to gain the olfactory tract. (4) *Nerve-fibre layer*.—This layer consists chiefly of the medullated axons of the mitral

FIG. 900.—A coronal section through the olfactory bulb. (Schwalbe.)



cells; a certain number of afferent fibres are also present, passing to end in the molecular layer. Most of these are derived from the olfactory bulb of the opposite side and cross the median plane in the anterior commissure. (5) *Neuroglial layer*.—A flattened ovoid mass of neuroglia occupies the site of the original cavity of the bulb, and is covered on its dorsal or upper aspect by a thin layer of scattered grey and white matter.

The regions of the olfactory pyramid and tubercle and, in fact, the whole of the anterior perforated substance, are irregularly broken up by bands of fibres and blood-vessels so that their structure shows no constant or regular arrangement. They are poorly developed areas in the human brain.

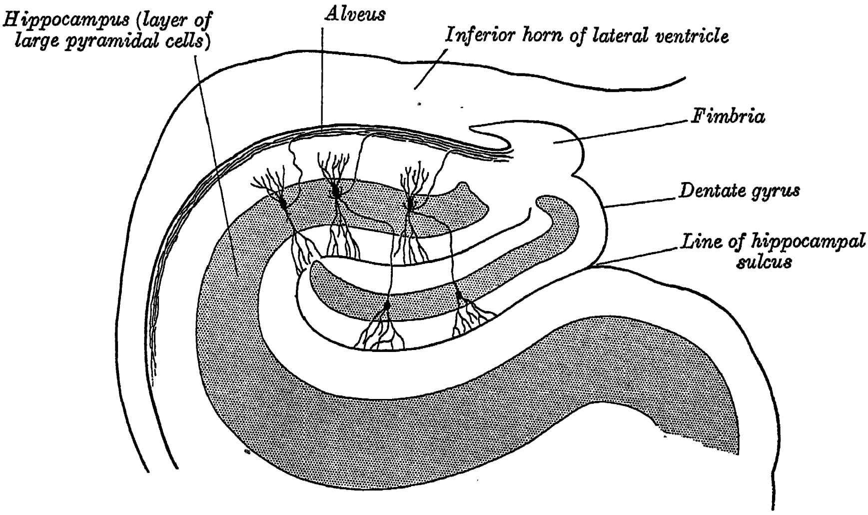
The **piriform area** shows a definitely stratified arrangement, which differs in certain respects from the cortex of the neopallium. The molecular layer is unusually deep and contains a large number of tangential fibres. The adjoining layer contains two varieties of cells, each arranged in clumps or cell-nests. The larger cells average 28μ in diameter, are stellate in form and poor in Nissl's bodies. The smaller cells, though pyramidal in form, are smaller than the most superficial of the pyramidal cells in the neopallium. The third layer is deep, and the cells which it contains are chiefly pyramidal in shape, and their apices point obliquely to the surface. These cells are especially rich in basal dendrites. The fourth layer is much shallower and contains remarkably few cells, some resembling those of the third layer, while others are small and stellate in shape. The fifth layer is thicker and contains cells which resemble

the pyramidal elements of the third layer. A sixth, deeper, layer of fusiform cells is also present.

This area receives the olfactory neurones of the second order and gives rise to those of the third order, which proceed to the hippocampal formation.

The hippocampus is more primitive in its structure than the piriform area and consists essentially of three layers. It represents a portion of the cortex which has been rolled into the inferior horn of the lateral ventricle and its superficial cortical layer lies in relation to the hippocampal sulcus anteriorly and to the dentate gyrus posteriorly. The superficial or *molecular layer* is unusually deep and is densely packed with tangential fibres. It is usually described as consisting of a superficial part, named the stratum moleculare, and a deep part, named the stratum lacunosum. This is succeeded by a thick layer of *large pyramidal cells,* which give off long apical dendrites into the molecular layer. Their basal axons run centrally through the succeeding polymorphous

FIG. 901.—Diagram of a coronal section through the hippocampus. After Villiger.



layer and pass into the subjacent white matter, which here constitutes the *alveus*. The numerous apical dendrites which are crowded together in the superficial part of this pyramidal layer have given rise to its subdivision into a *stratum radiatum* (or dendritic part) and a *stratum lucidum* (or cellular part). The third layer contains *polymorphous cells* some of which are cells of Martinotti. Here, as elsewhere, they send their axons into the molecular layer. Others are aberrant pyramidal cells, while others, again, send their axons into the pyramidal layer, where they end by arborising around the pyramidal cells.

The white fibres of the alveus cover the polymorphous layer and separate it from the ependyma on the free, ventricular surface of the hippocampus (fig. 901).

The *dentate gyrus* also consists of three layers, viz. a molecular layer, a granular layer and a polymorphous layer. The *molecular stratum* is well developed, and receives the dendrites of the cells of the second layer. These are, for the most part, small granule-cells, but a number of large pyramidal cells are found amongst them. The axones of these cells traverse the third, or polymorphous layer, and then enter the adjoining molecular layer of the hippocampus (fig. 901), through which they pass to reach the pyramidal layer, where they terminate by arborising round the large pyramidal cells. These axons are characterised by small varicosities which are placed on them as they run in the pyramidal layer. The third, or polymorphous layer, contains many Golgi cells, type II, and many cells which send their axons through the adjoining layers of the hippocampus to reach the alveus.

The curious interlocking which occurs in the region of the hippocampus and the dentate gyrus (fig. 901) requires explanation. As the hippocampal form-

ation becomes defined, the cells which ultimately form the dentate gyrus lie on the fringe of the pallium and immediately adjoin the choroidal fissure. The constituent cells of the formation proliferate rapidly, and as a result they form an elevation which protrudes into the cavity of the ventricle. The cells which form the intermediate layer of the hippocampus are directly continuous with the granular layer of the neopallium on the one hand and with the intermediate layer of the dentate gyrus on the other. As growth proceeds, however, the continuity with the cells of the dentate gyrus is broken, and the latter, as seen on transverse section (fig. 901), forms an isolated strip which has all the appearance of being inserted, secondarily, into the infolded cortex of the hippocampus. As a result, the molecular layer of the dentate gyrus is in direct contact with the corresponding layer of the hippocampus. The hippocampal sulcus, when it is present, intervenes between them. The polymorphous layer of the dentate gyrus is also in contact with the molecular layer of the hippocampus, which has extended over its dorsal, or superior, aspect (fig. 901).

MYELINATION

Flechsig has shown that the white fibres of the cerebral hemisphere do not all acquire their myelin sheaths at the same period. The process commences in the eighth month of intra-uterine life and involves first the afferent fibres passing to the somesthetic area in the postcentral gyrus and the afferent fibres to the hippocampal formation. While the nerve-fibres in these areas are receiving their medullary sheaths, the process commences in the afferent fibres leading to the visuosensory and the auditosensory cortical areas. Myelination of the great, efferent cerebrospinal pathway is not completed until the middle of the third month after birth. As it is generally believed that nerve-fibres are incapable of conducting impulses until they have acquired their myelin sheaths, it follows that all the movements which the infant carries out in the first two months of life are reflex movements, depending on the spinal cord and the brain stem. Subsequently the fibres of the psychic portions of the motor and somesthetic areas and of the visuo- and auditopsychic areas acquire their sheaths, and it is not until this process is well established that the child is able to benefit by past experience or is able to perform voluntary acts as distinct from reflex movements. Last of all, the fibres of the large association areas (frontal, parietal and temporal) become myelinated and in these areas the process may not be finally completed until the eighteenth year or even later. Complete mental development is not possible until these areas can be utilised, and it would appear that there is considerable individual variation in the age period at which the myelination of the fibres of the association areas is completed. (See also p. 1022.)

THE CEREBRAL COMMISSURES AND THE SEPTUM LUCIDUM

At the end of the second month of development the two cerebral hemispheres, whose large cavities communicate with the anterior part of the third ventricle, are connected to each other by the anterior wall of the third ventricle (*lamina terminalis*) and by the anterior parts of its roof and floor. The roof at this stage is formed of a single layer of ependyma only and remains so throughout life. It therefore does not offer any pathway to fibres which, arising on one side of the cerebrum, are seeking to reach the other. The floor, on the other hand, is actively concerned with the development of the optic chiasma, the tuber cinereum and the hypophysis cerebri. It is therefore to the undeveloped region of the lamina terminalis that the commissural fibres travel in order to gain the opposite side. The earliest commissural fibres to develop are associated, as might be expected, with the rhinencephalon, and they constitute two distinct bundles. The *anterior commissure* occupies the lower part of the lamina terminalis and consists of fibres which connect the olfactory bulbs, the olfactory pyramids and the piriform areas. The second commissural bundle

connects the two fornix systems, and through them the hippocampal formations, and naturally traverses the upper part of the lamina. It is termed the *hippocampal commissure.* The development of these commissures leads to local thickenings of the lamina terminalis, and when the commissural fibres of the neopallium develop, they follow the paths which have already been prepared. A few fibres from the temporal area join the anterior commissure, but the bulk of the neopallial fibres accumulate on the dorsal aspect of the hippocampal commissure and develop into the *corpus callosum.* In the fifth month the corpus callosum forms a curved band which projects forwards from the upper part of the lamina terminalis and is in close relationship at its posterior end with the upper and posterior part of the hippocampal commissure. The cortical area which occupies the angular interval below the projecting anterior end of the corpus callosum is named the *paraterminal gyrus* and it extends downwards in front of the whole length of the lamina terminalis. With the subsequent formation of the rostrum, which recurves downwards and backwards, the connexion between the upper part of the paraterminal gyrus and the rest of the area becomes severed. The included portion is thinned out and stretched by the general growth of the corpus callosum and the fornix and becomes the *septum lucidum* * (septum pellucidum). While these changes, which have not yet been observed in their entirety, are occurring at the anterior end of the corpus callosum, its posterior end increases rapidly in bulk and together with the hippocampal commissure is carried backwards above the epithelial roof of the third ventricle. As it passes backwards, it lies above the line of the choroidal fissure and invades the upper part of the hippocampal formation, which consequently becomes thinned out on its surface to form the indusium griseum. Owing to this backward growth, the corpus callosum and the hippocampal commissure form an additional and secondary roof for the third ventricle. It must be remembered, however, that the narrow interval between the commissures above and the epithelial roof of the third ventricle below is really an extra-cerebral space and that the transverse fissure, which lies below the splenium of the corpus callosum and leads into this interval, is not a cerebral fissure in the true sense of the words.

In its backward growth the corpus callosum does not extend so far as the lower part of the choroidal fissure, and it therefore makes no inroad into that part of the hippocampal formation which is associated with the inferior horn of the ventricle and which gives rise to the dentate gyrus and the hippocampus. In the light of the development of the corpus callosum, the continuity of the hippocampus and the dentate gyrus with the indusium griseum (p. 985) becomes intelligible.

The **corpus callosum** is the great transverse commissure which connects the cerebral hemispheres and roofs in the lateral ventricles. A good conception of its position and size is obtained by examining a median sagittal section of the brain (fig. 884). It forms an arched structure about 10 cm. in length, its anterior end being about 4 cm. from the frontal poles and its posterior end about 6 cm. from the occipital poles of the hemispheres.

The *genu*, which forms the anterior end, is bent downwards and backwards in front of the septum lucidum and, diminishing rapidly in thickness, is prolonged backwards to the upper end of the lamina terminalis as the *rostrum.* The *trunk* arches backwards with an upward convexity and terminates posteriorly in the *splenium*, which is the thickest part of the corpus callosum. A sagittal section of the splenium shows that the posterior end of the corpus callosum is bent forwards acutely, the upper and lower parts being applied closely to each other.

The upper surface of the *trunk* of the corpus callosum, which is 2·5 cm. wide, is covered by a thin layer of grey substance, termed the *indusium griseum.* This grey covering extends round the genu to the inferior surface of the rostrum, and in it are imbedded two fine longitudinal bundles of fibres on each side, which are termed the medial and lateral longitudinal striæ (p. 986).

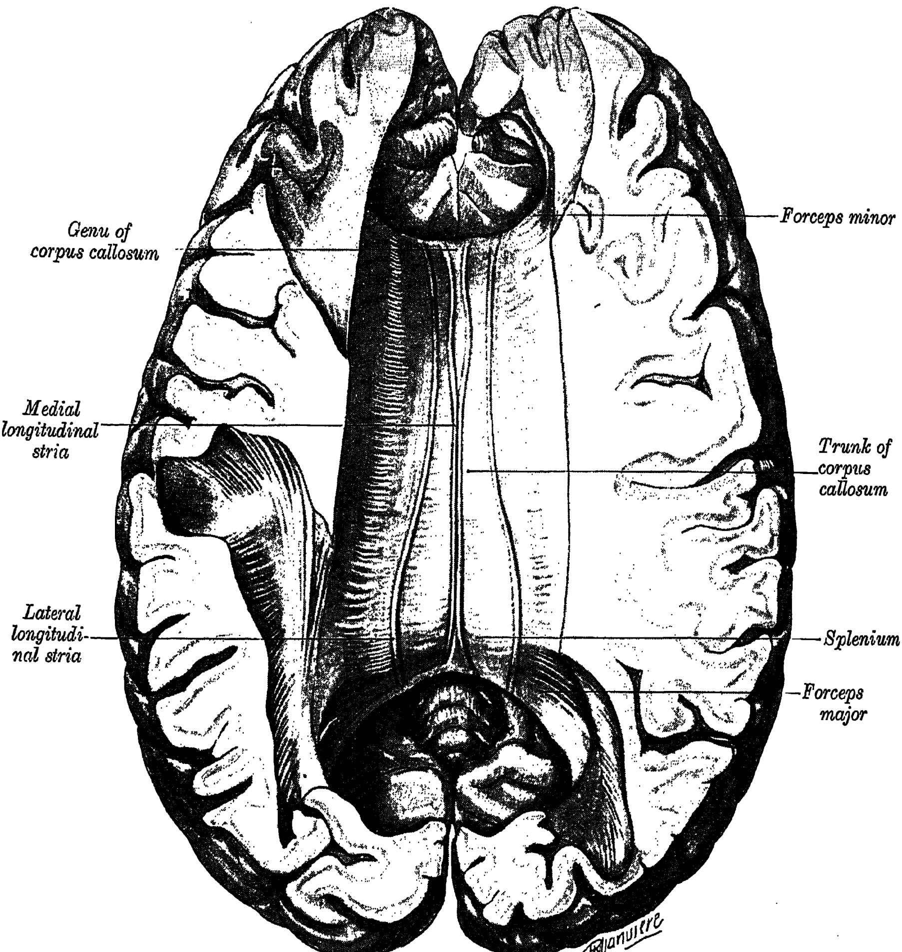
In the median plane the trunk of the corpus callosum forms the floor of the longitudinal fissure, and is related to the anterior cerebral vessels and to the lower border of the falx cerebri, which may come into actual contact with it

* A somewhat different view of the origin of the septum lucidum is given by J. Maclaren Thompson, *Journal of Anatomy*, vol. lxvii.

posteriorly. On each side of the median plane the trunk is overlapped by the gyrus cinguli, from which it is separated by the slit-like callosal sulcus.

The inferior surface of the trunk is concave in its long axis and convex from side to side. In the median plane, it gives attachment to the septum lucidum anteriorly, and the extent of this attachment depends on the length of the septum (fig. 884). Posteriorly it is fused with the body of the fornix and the hippocampal commissure. On each side of the median plane, the inferior surface of the trunk forms the roof of the lateral ventricle (fig. 904) and is covered with the ventricular ependyma.

FIG. 902.—The corpus callosum. Exposed from above.



The *genu* is continuous above with the trunk and below with the rostrum. Its anterior surface, which is in relation to the anterior cerebral vessels, is covered with the indusium griseum and the longitudinal striæ. Its posterior surface gives attachment to the septum lucidum in the median plane, and on each side it forms the anterior wall of the anterior horn of the lateral ventricle.

The *rostrum* connects the genu to the upper end of the lamina terminalis. In the median plane its superior surface gives attachment to the septum lucidum and, on each side, forms the narrow floor of the anterior horn of the lateral ventricle (fig. 916). On the inferior surface of the rostrum the indusium griseum and the longitudinal striæ are carried backwards to the upper end of the paraterminal gyrus.

The *splenium* overhangs the posterior ends of the thalami, the pineal body and the tectum of the mid-brain. It is, however, separated from them by a number of structures. On each side of the median plane the posterior column

(crus) of the fornix and the splenial gyrus (fasciola cinerea) (fig. 903) curve upwards to reach the splenium. The posterior column of the fornix continues forwards on the under surface of the trunk, but the splenial gyrus passes round the splenium, rapidly tapering off and fading away into the indusium griseum. In the median plane, the tela chorioidea passes forwards below the splenium through the transverse fissure and the internal cerebral veins emerge from between its two layers and unite to form the great cerebral vein. Superiorly the splenium is covered with the indusium griseum and is related to the falx cerebri and the inferior sagittal sinus in the median plane, and to the gyrus cinguli on each side. Posteriorly the splenium is related to the free margin of the tentorium cerebelli, the great cerebral vein and the commencement of the straight sinus.

The fibres of the corpus callosum radiate into the white matter of the hemisphere on each side and pass to the various parts of the cerebral cortex.

FIG. 903.—A dissection of a coronal section of the brain to display the splenium of the corpus callosum from in front.

The posterior portions of the thalami have been removed. Observe that the arrangement of the fimbria relative to the dentate gyrus was different on the two sides of this specimen.

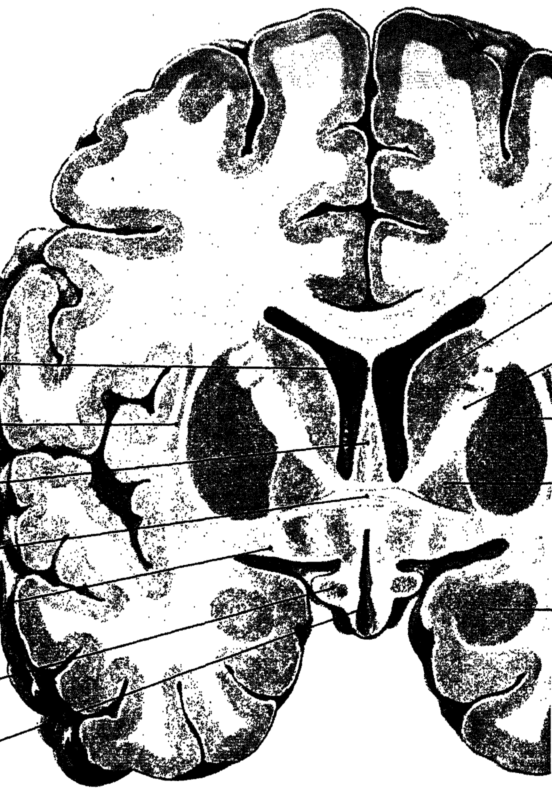
The fibres of the rostrum pass laterally below the anterior horns of the lateral ventricles, and connect the orbital surfaces of the two frontal lobes. The fibres of the genu curve forwards and connect the lateral and medial surfaces of the two frontal lobes, constituting the *forceps minor* (forceps anterior). The fibres of the trunk pass laterally and intersect the itinerant fibres of the corona radiata (fig. 873). They connect wide cortical areas of the two hemispheres to one another. Those fibres of the body and of the splenium which together form the roof and lateral wall of the posterior horn, and the lateral wall of the inferior horn of the ventricle constitute the *tapetum* (p. 1004). The remaining fibres of the splenium curve backwards and medially into the occipital lobes and form the *forceps major* (forceps posterior). This large bundle of fibres bulges into the upper part of the medial wall of the posterior horn of the ventricle and forms a curved elevation which is termed the bulb of the posterior cornu.

The **anterior commissure** is a bundle of white fibres which crosses the median plane in front of the columns of the fornix in the anterior wall of the third ventricle (fig. 881). On sagittal section it is oval in shape, its long diameter being vertical and measuring about 5 mm. Its constituent fibre bundles are twisted like the strands of a rope, and they curve backwards and laterally, forming a deep groove on the inferior aspect of the anterior part of the corpus striatum

(fig. 904). Many of the fibres belong to the rhinencephalon and connect the olfactory bulbs and pyramids and the piriform areas. Others belong to the neopallium and can be traced into the temporal lobes, where they spread out like the frayed end of a rope so that their precise connexions are difficult to determine.

The **hippocampal commissure** forms a thin sheet of transverse fibres which connects the medial edges of the posterior columns of the fornix and is closely applied to the under surface of the posterior part of the trunk of the corpus callosum. Its constituent fibres are derived from the pyramidal cells of the hippocampus and traverse the alveus and the fimbria in order to reach the posterior column of the fornix. Having crossed the median plane in the commissure, they retrace their course on the opposite side and terminate in the

Fig. 904.—A coronal section passing through the brain just behind the optic chiasma and exposing the anterior commissure as it crosses the median plane.



molecular layer of the hippocampus. This commissure therefore functions as the pallial commissure of the rhinencephalon.

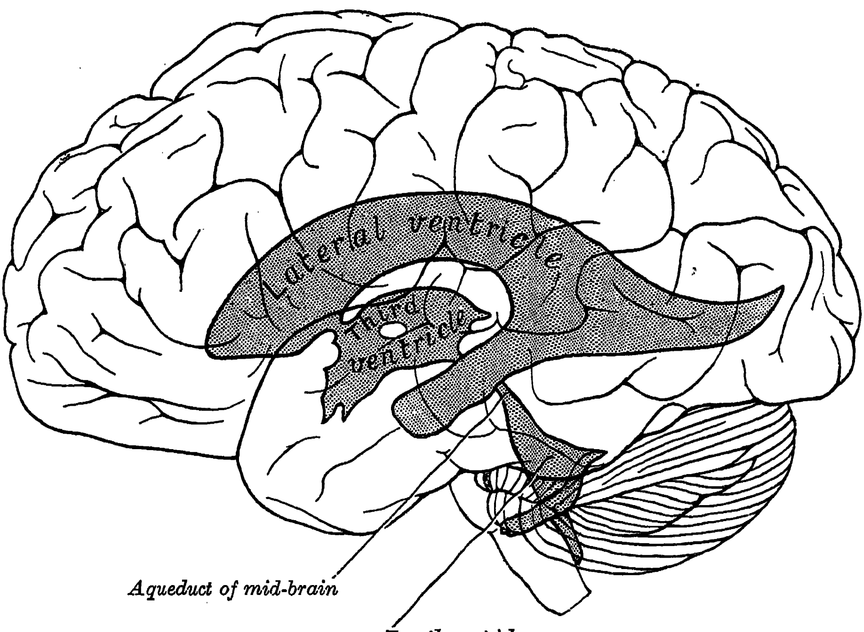
The **septum lucidum** (septum pellucidum) is a thin vertical partition, consisting of two laminæ, separated throughout a greater or lesser part of their extent by a narrow interval, termed the *cavity of the septum lucidum,* which does not communicate with the ventricles of the brain. It is triangular in form, with its base in front and its apex behind. It is attached above to the inferior surface of the trunk of the corpus callosum; below and behind, to the anterior part of the fornix; below and in front, to the upper surface of the rostrum of the corpus callosum. The lateral surface of each lamina takes part in the formation of the medial wall of the anterior horn and body of the lateral ventricle, and is therefore covered with ependyma.

The laminæ contain both grey and white matter, but they are so thin that the arrangement of their constituents does not afford much help in determining their phylogenetic history. The development of the septum lucidum is referred to on p. 999.

THE INTERIOR OF THE HEMISPHERES

The lateral ventricles (figs. 907-910).—The two lateral ventricles are irregular cavities situated in the lower and medial parts of the cerebral hemispheres, one on each side of the median plane. They are almost completely separated from each other by a median vertical partition, termed the *septum lucidum*, but they communicate with the third ventricle and indirectly with each other through the *interventricular foramen* (p. 969). They are lined with ciliated epithelium (*ependyma*), and contain cerebrospinal fluid, which, even in health, may be secreted in considerable amount. Each lateral ventricle consists of a *central part* and three *cornua* or *horns* (anterior, posterior and inferior) (figs. 907, 908).

FIG. 905.—A scheme showing the relations of the ventricles to the surface of the brain.



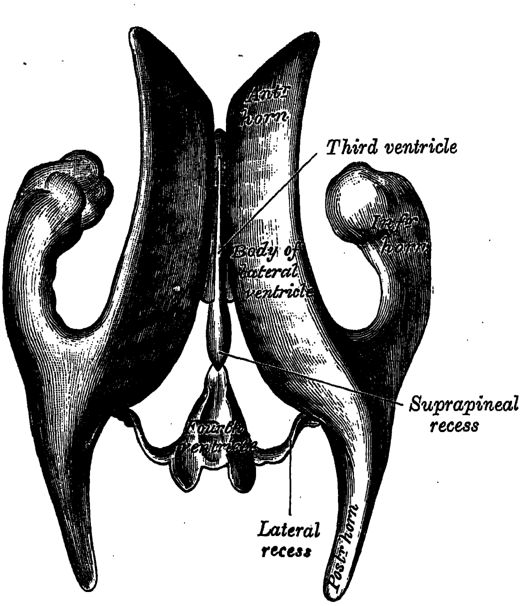
The **central part** (fig. 907) of the lateral ventricle extends from the interventricular foramen to the splenium of the corpus callosum. It is an irregularly curved cavity, triangular on transverse section, with a roof, a floor, and a medial wall. The roof is formed by the under surface of the corpus callosum ; the floor, which is slightly concave upwards and medially, by the following parts, named in their order of position from the lateral to the medial side : the caudate nucleus of the corpus striatum, the stria semicircularis (stria terminalis) and the thalamostriate vein (vena terminalis), the lateral portion of the upper surface of the thalamus, the choroid plexus, and the lateral part of the fornix. The caudate nucleus becomes rapidly narrower as it is traced backwards in the floor, and its long axis is directed laterally as well as posteriorly. The stria semicircularis, a small bundle of white fibres (p. 1014), and the thalamostriate vein occupy a narrow groove which follows the medial border of the caudate nucleus and separates it from the lateral margin of the upper surface of the thalamus. The latter may be almost entirely hidden by the vascular fringe of the choroid plexus, which invaginates the ependyma into the cavity through the slit-like interval between the lateral margin of the fornix and the upper surface of the thalamus. This ependymal invagination constitutes the choroidal fissure. The body of the fornix becomes wider as it is traced backwards, and its thin, lateral margin lies parallel with the groove for the stria semicircularis.

The medial wall is formed by the posterior part of the septum lucidum. Posteriorly, where the septum lucidum ends, the roof and the floor meet one another on the medial wall.

The **anterior cornu** (fig. 907) passes forwards, laterally and slightly downwards, into the frontal lobe, curving round the large swelling caused by the head or anterior end of the caudate nucleus. In a coronal section it appears as a triangular slit below the anterior part of the corpus callosum, and it is bounded anteriorly by the posterior surface of the genu of the corpus callosum. The greater part of the floor is formed by the rounded head of the caudate nucleus, but, in its medial portion, a small part is formed by the upper surface of the rostrum of the corpus callosum (fig. 916).

The **posterior cornu** curves backwards and medially into the occipital lobe. Its roof and lateral wall are formed by fibres of the tapetum of the corpus callosum, which separate them from the optic radiation (p. 1010). The splenial fibres which constitute the forceps major pass medial to the posterior cornu as they sweep backwards into the occipital lobe. In this part of their course they produce a rounded ridge in the upper part of the medial wall, which is named the *bulb* of the posterior cornu. Below the bulb, a second elevation may be identified on the medial wall. It receives the fanciful name of the *calcar avis*, and it corresponds to the infolded cortex of the calcarine sulcus (fig. 908). Posteriorly the lateral and medial walls meet each other.

Fig. 906.—A drawing of a cast of the ventricular cavities. Superior aspect. (Retzius.)



The **inferior cornu** (fig. 910), the largest of the three, traverses the temporal lobe, forming in its course a curve round the posterior end of the thalamus. It passes at first backwards, laterally, and downwards, and then curves forwards to within 2·5 cm. of the apex of the temporal lobe, its position being fairly well indicated on the surface of the brain by the superior temporal sulcus. Its roof is formed chiefly by the inferior surface of the tapetum of the corpus callosum, but the tail of the caudate nucleus and the stria semicircularis (stria terminalis) also extend forwards in the roof, at the extremity of which they end in a mass of grey matter, named the *amygdaloid nucleus*. Its floor presents the following parts : the choroid plexus, the fimbria hippocampi, the hippocampus and the collateral eminence. The choroid plexus is a vascular fringe which covers the upper surface of the fimbria and the hippocampus. It invaginates the ependymal medial wall of the inferior cornu and so forms the lower part of the choroidal fissure.

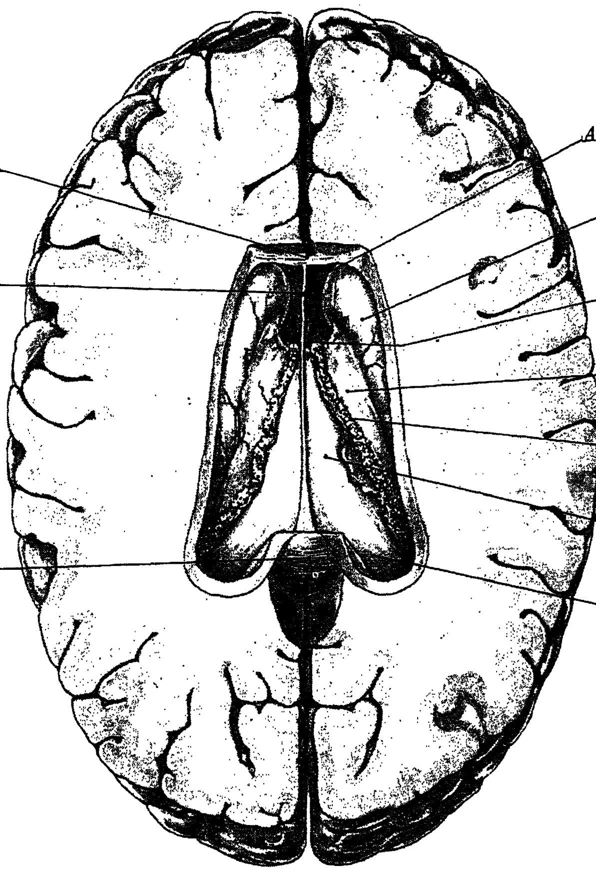
The fimbria and the hippocampus have already been considered (pp. 986 and 987), and a full description of the choroid plexus will be found on p. 1014.

The *collateral eminence* (fig. 910) is an elongated swelling lying lateral to and parallel with the hippocampus. It corresponds with the middle part of the collateral sulcus, and its size depends on the depth and direction of this sulcus. It is continuous behind with a flattened triangular area, named the *trigonum collaterale,* situated between the posterior and inferior cornua.

The white matter of the hemispheres.—If the upper parts of the hemisphere be sliced off about 1·25 cm. above the corpus callosum, the central white matter of the hemisphere is seen as an oval area surrounded by a narrow convoluted margin of grey matter, and studded with red dots (puncta vasculosa)

produced by the escape of blood from divided blood-vessels. If the hemispheres be sliced off at the level of the corpus callosum, the white matter of that structure will be seen in continuity with the white matter of the hemisphere on each side. The white matter consists of medullated fibres, of varying size, supported by neuroglia. These fibres may be divided, according to their course and connexions, into three systems: (1) The commissural fibres connect corresponding areas in the two hemispheres to each other. (2) The association fibres connect different cortical areas of the same hemisphere to one another;

FIG. 907.—The central parts and the anterior cornua of the lateral ventricles. Exposed from above.



some of them are collateral branches of the itinerant (projection) and commissural fibres, but the majority are the axons of independent cells. (3) The itinerant (projection) fibres connect the cerebral cortex with the brain-stem and the spinal cord.

(1) The **commissural fibres** have already been considered (p. 998).

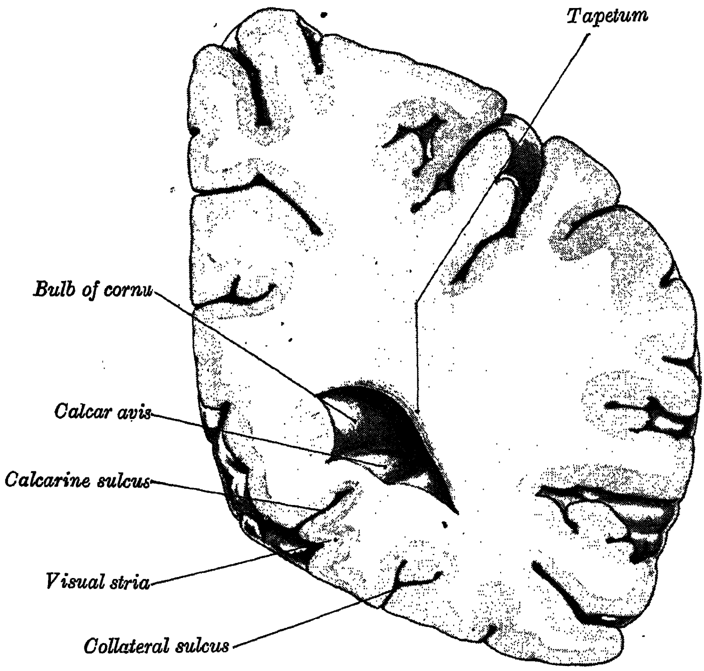
(2) The **association fibres**, which are all homolateral, are of two kinds: (*a*) short association fibres, connecting adjacent gyri to one another; (*b*) long association fibres, connecting more widely separated gyri to one another.

The *short association fibres* may be intracortical or they may lie immediately beneath the cortex and connect adjacent gyri, some merely passing from one wall of a sulcus to the other.

The *long association fibres* group themselves, somewhat indistinctly, into bundles, which can be dissected in the formalin-hardened brain after the cortex and the subjacent short association fibres have been removed. The fibres in each fasciculus show considerable variation in length, and the longest are always situated in the deepest part of the bundle. The following fasciculi can

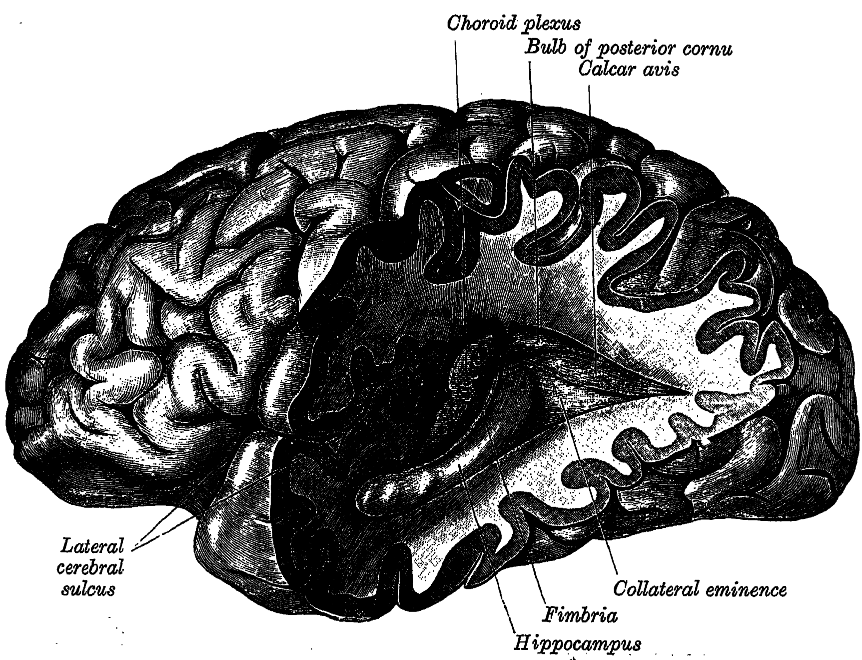
be distinguished : (*a*) the uncinate fasciculus ; (*b*) the cingulum ; (*c*) the superior longitudinal fasciculus ; (*d*) the inferior longitudinal fasciculus ; (*e*) the fronto-occipital fasciculus.

Fig. 908.—A coronal section through the posterior cornu of the left lateral ventricle. Anterior aspect.



(*a*) The *uncinate fasciculus* connects the gyri on the orbital surface of the frontal lobe with the anterior part of the temporal lobe. The fibres follow a

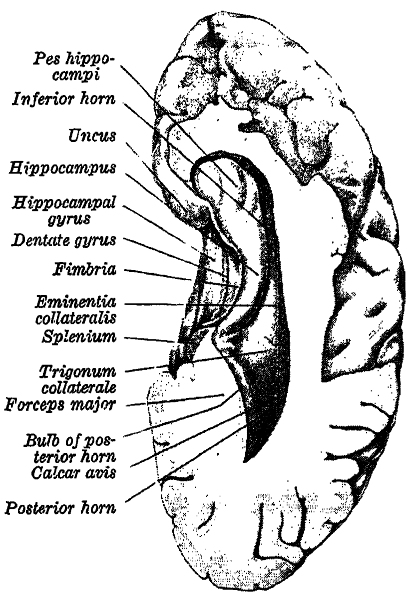
Fig. 909.—The posterior and inferior horns of the left lateral ventricle. Exposed from the side.



sharply curved course and cross the floor of the stem of the lateral sulcus. They are related to the antero-inferior part of the insular area.

(*b*) The *cingulum* is a long, curved bundle which commences on the medial surface of the hemisphere below the rostrum of the corpus callosum. It lies within the gyrus cinguli and so follows the curve of that gyrus. Inferiorly it enters the hippocampal gyrus and spreads out so as to reach the adjoining parts of the temporal lobe.

Fig. 910.—The posterior and inferior horns of the right lateral ventricle. Exposed from above.

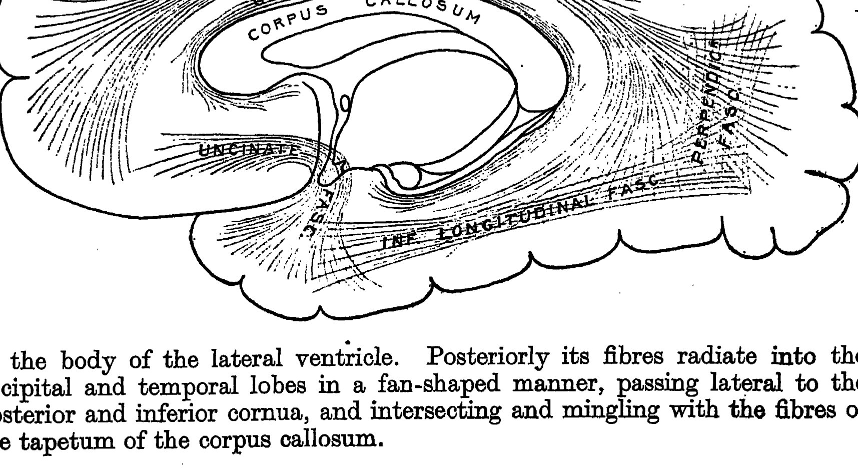


(*c*) The *superior longitudinal fasciculus* is the largest of all the association bundles. It commences in the anterior part of the frontal region and arches backwards above the insular area and lateral to the base of the corona radiata (p. 1009). After giving off a number of fibres to the occipital cortex, it curves downwards and forwards behind the insular area and spreads out into the temporal lobe.

(*d*) The *inferior longitudinal fasciculus* commences near the occipital pole and its fibres are derived from the whole extent of the occipital cortex. They sweep forwards, separated from the posterior horn of the lateral ventricle by the fibres of the optic radiation and the commissural fibres of the tapetum, and after being crossed by the superior longitudinal fasciculus, are distributed throughout the temporal lobe.

(*e*) The *fronto-occipital fasciculus* commences at the frontal pole and passes backwards on a deeper plane than the superior longitudinal fasciculus and separated from it by the base of the corona radiata (p. 1009). It associates itself with the lateral border of the caudate nucleus, and is therefore closely related

Fig. 911.—A diagram showing the principal system of association fibres in the cerebrum.



to the body of the lateral ventricle. Posteriorly its fibres radiate into the occipital and temporal lobes in a fan-shaped manner, passing lateral to the posterior and inferior cornua, and intersecting and mingling with the fibres of the tapetum of the corpus callosum.

Fig. 912.—A dissection showing some of the long association bundles of the right cerebral hemisphere.

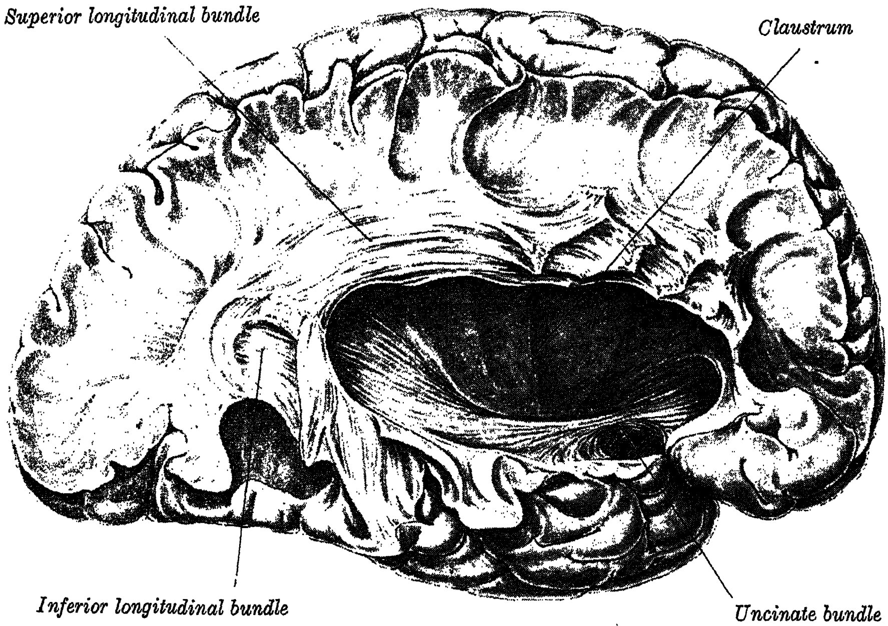
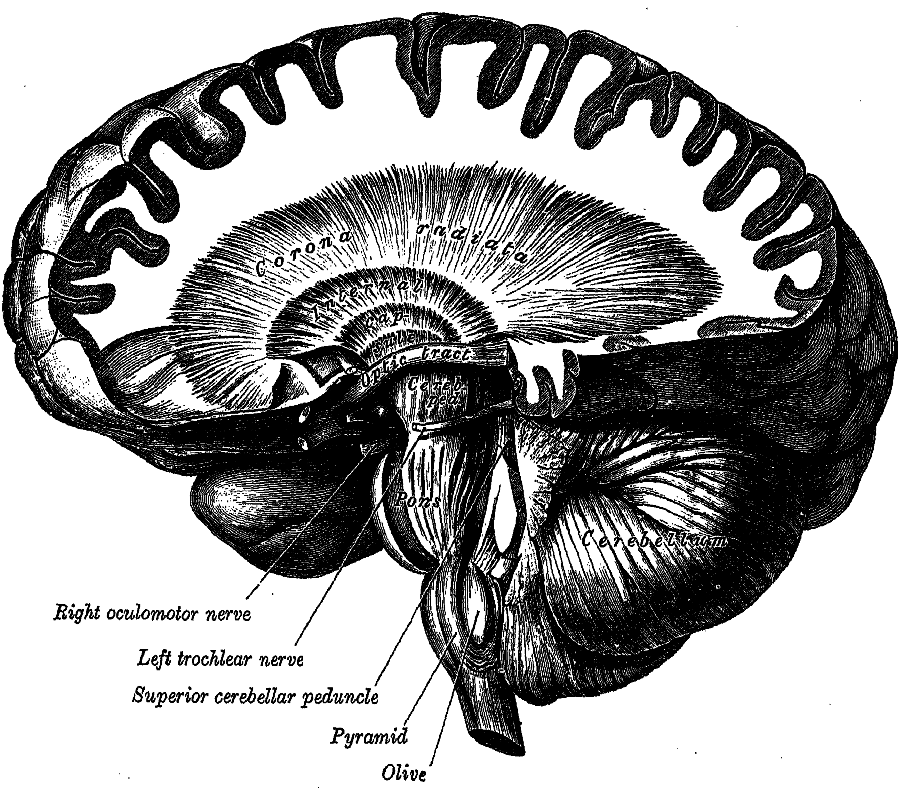


Fig. 913.—A dissection showing the course of the cerebrospinal fibres. (E. B. Jamieson.)

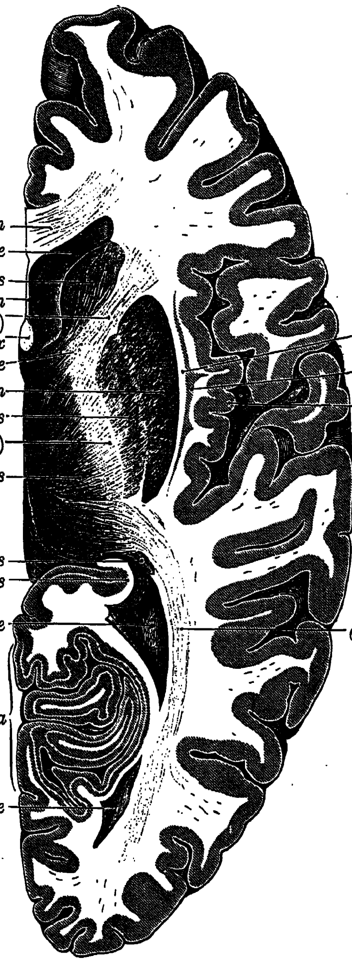


(3) The **itinerant fibres** (projection fibres) connect the cerebral cortex with the lower parts of the brain (including the diencephalon) and the spinal cord, and include both corticofugal and corticopetal fibres.

The *itinerant fibres of the archipallium* form the *fornix*, which has been considered elsewhere (p. 986).

The *itinerant fibres of the neopallium* converge from all directions on the corpus striatum (fig. 914). For the most part they lie deep to the association fibres, and they intersect the commissural fibres of the corpus callosum and the

FIG. 914.—A horizontal section through the right cerebral hemisphere. Superior aspect.



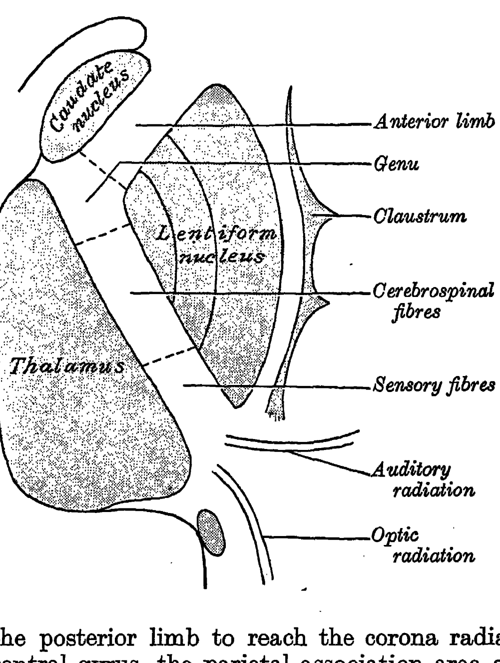
anterior commissure. As they approach the periphery of the corpus striatum, they emerge from this intersection and form the *corona radiata*. The medial aspect of the corona radiata is separated from the lateral ventricle by the fronto-occipital fasciculus, and its lateral aspect is covered by the superior longitudinal fasciculus. Below, the corona radiata is directly continuous with the internal capsule, a thick, curved band of white matter which comprises all the itinerant fibres of the neopallium, and which cuts into the corpus striatum, dividing it almost completely into two parts, viz. the lentiform and the caudate nuclei.

A transverse, horizontal section through the cerebral hemisphere shows the **internal capsule** as a broad band of white fibres, bent with an outward concavity, which accommodates itself to the convex medial surface of the lentiform nucleus (fig. 914). It can therefore be divided into an *anterior limb* (frontal

part), a *genu*, a *posterior limb* (occipital part) and a *retrolentiform part*. The anterior limb is interposed between the lentiform nucleus on the lateral side and the head of the caudate nucleus on the medial side. The posterior limb has the thalamus on its medial side and the lentiform nucleus on its lateral side. The fibres of the internal capsule continue to converge as they pass downwards, and at the same time the frontal fibres tend to pass backwards and medially, while the occipital fibres pass forwards and laterally. At the lower limit of the lentiform nucleus, they are crossed by the optic tract and enter the mid-brain. The corticofugal fibres enter the base of the cerebral peduncle, where the frontal fibres are placed to the medial side and the occipital fibres to the lateral side. The corticopetal fibres ascend from the tegmentum.

The *anterior limb* of the internal capsule contains: (1) *frontopontine fibres*, which arise in the cortex of the frontal area and are relayed in the nuclei pontis to the cerebellar hemisphere of the opposite side; (2) *thalamocortical fibres*, which arise, for the most part, in the medial nucleus of the thalamus and proceed to the frontal area.

Fig. 915.—Scheme showing the different parts of the internal capsule.



The *genu, posterior limb* and *retrolentiform part* contain: (1) the *great motor pathway*, which arises from the Betz cells of the precentral area. These fibres occupy the genu and rather more than the anterior half of the posterior limb. Experimental work has shown that the fibres are grouped in a definite manner in the internal capsule. The eyes, head, mouth, tongue and larynx are represented in the genu and adjoining part of the posterior limb; posterior to these are the fibres which represent the neck, upper limb, trunk and lower limb, in that order.

(2) *Thalamocortical fibres*, which arise in the lateral nucleus of the thalamus and traverse the posterior limb to reach the corona radiata and, subsequently, the postcentral gyrus, the parietal association area and the lips of the lateral sulcus. Many of these fibres are intermingled with the motor fibres, but others occupy a more posterior position.

(3) *Temporopontine fibres*, which arise in the cortex of the temporal lobe and are relayed in the nuclei pontis to the opposite side of the cerebellum.

(4) *Fibres of the auditory radiation*, which arise in the medial geniculate body and traverse the posterior part of the internal capsule. They sweep laterally and forwards, below and behind the lentiform nucleus, to gain the auditosensory area.

(5) *Fibres of the optic radiation*, which arise in the lateral geniculate body and sweep backwards through the retrolentiform part of the internal capsule, to reach the visuosensory area. In their course they are intimately related to the posterior horn of the ventricle and are only separated from it by the tapetum (fig. 914). Some of the fibres of the optic radiation are corticofugal and are destined for the superior corpus quadrigeminum and, possibly, the pulvinar (p. 958).

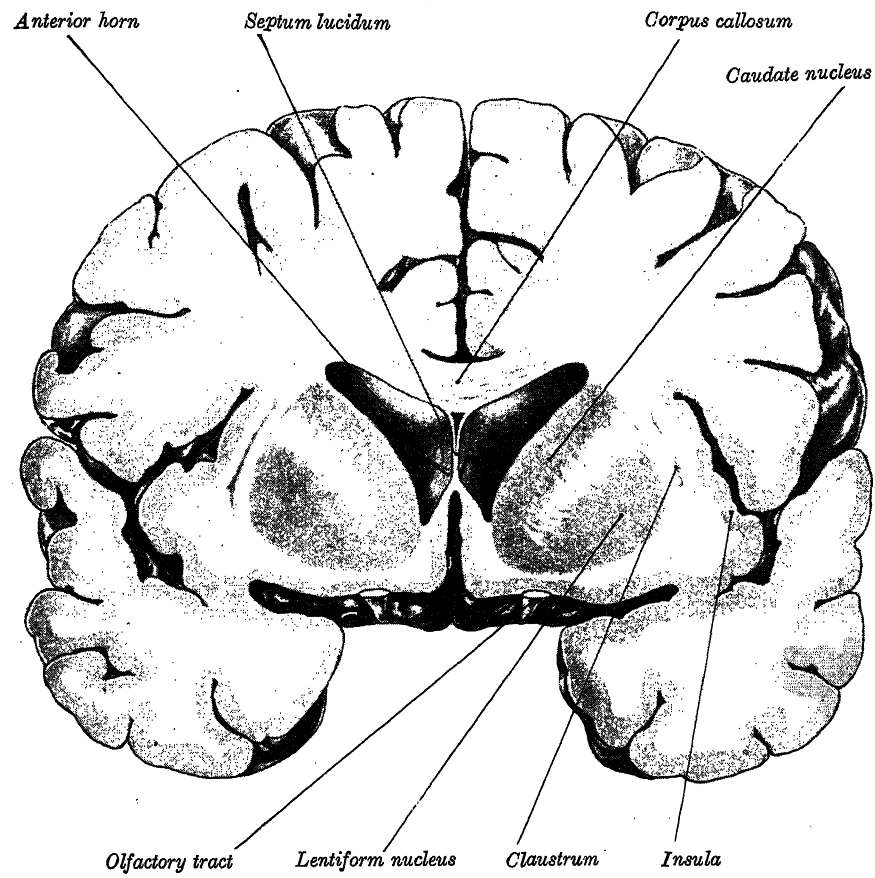
(6) *Corticothalamic fibres*, which arise chiefly in the temporal and occipital areas and pass to the lateral nucleus of the thalamus.

THE BASAL NUCLEI

The **basal nuclei** (basal ganglia) include those subcortical masses of grey matter which are found within the cerebral hemisphere. They comprise the corpus striatum, incompletely subdivided into the lentiform and the caudate nuclei, the amygdaloid nucleus and the claustrum.

The **corpus striatum** is a mass of grey matter which develops in the ventral part of the primitive hemisphere in the area immediately adjoining the interventricular foramen. It is therefore not far distant from that part of the lateral wall of the diencephalon which gives rise to the thalamus. At first the

FIG. 916.—A coronal section through the anterior horns of the lateral ventricles.



corpus striatum is separated from the thalamus by a deep groove on the surface of the brain, but as the two masses enlarge, the groove is filled out. The thalamus and the corpus striatum therefore come into close contact with each other. When the itinerant fibres (projection fibres) develop (p. 121) they cut into the corpus striatum and, save in its most anterior part, separate it into a lateral part, the lentiform nucleus, and a medial part, the caudate nucleus. The cleft so formed passes through the corpus striatum obliquely so that the itinerant fibres of the internal capsule separate the lentiform nucleus completely from the thalamus.

The **caudate nucleus** is an arcuate mass of grey matter, which has already been seen in the floor of the anterior horn and body of the lateral ventricle and in the roof of the inferior horn. Its massive, rounded *head* projects into the cavity of the anterior horn, forming the greater part of its floor. This surface is covered with the ventricular ependyma, and is related above to the

corpus callosum. Laterally it is separated from the lentiform nucleus by the anterior limb of the internal capsule, but this separation is complete only in its upper part. Below, the lateral aspect of the head is directly continuous with the putamen of the lentiform nucleus, and over the intermediate area strands of grey matter traverse the internal capsule and connect the two nuclei to each other (fig. 916). The striped appearance which this region presents has given origin to the term corpus striatum. Superiorly the margin of the head is related to the fronto-occipital association bundle (p. 1007). Posteriorly the head rapidly diminishes in bulk and becomes continuous with the body of the nucleus, which lies in the lateral part of the floor of the lateral ventricle.

The *body* arches upwards, backwards and laterally. Its medial aspect is covered with ependyma and related to the thalamostriate vein (vena terminalis), the stria semicircularis (stria terminalis) and the thalamus. Laterally it is related to the fronto-occipital bundle above, and to the corona radiata below. Posteriorly it turns downwards at the posterior extremity of the thalamus and becomes continuous with the tail.

The *tail* of the caudate nucleus runs forwards in the roof of the inferior horn of the lateral ventricle, with the stria semicircularis to its medial side (fig. 903). As the body curves downwards and forwards into the tail it passes below the corona radiata, the globus pallidus of the lentiform nucleus and the ansa lenticularis (p. 963). Anteriorly the tail of the caudate nucleus is continuous with the amygdaloid nucleus.

The **lentiform nucleus** is shaped like a biconvex lens, but the curvature of its medial surface is sharper than the curvature of its lateral surface. Cut on section, it is seen to consist of two portions, which differ from each other in their colour. The larger lateral portion, which is dark in colour, is termed the *putamen* ; the smaller medial portion is of a lighter tint, and is termed the *globus pallidus*.

The lentiform nucleus is completely buried in the substance of the hemisphere. Laterally it is covered by a thin layer of white matter which constitutes the *external capsule*. This sheet is covered on its lateral side by the *claustrum*, which intervenes between it and the subcortical white matter of the insula. Medially the lentiform nucleus is in relation to the internal capsule, which separates it from the thalamus behind, and from the head of the caudate nucleus in front. Round its anterior, superior and posterior margins the nucleus is related to the corona radiata. The inferior part of the lentiform nucleus is deeply grooved by the anterior commissure as it passes backwards and laterally into the temporal lobe (fig. 904), and anteriorly it is continuous with the head of the caudate nucleus. A little in front of the groove, the grey matter of the corpus striatum is continuous with the grey matter of the anterior perforated substance, and the lateral striate arteries, which enter the brain there, run laterally and then turn upwards, in close contact with the lateral surface of the lentiform nucleus, before they pierce its substance. The lentiform nucleus lies above the inferior horn of the lateral ventricle and is separated from it by the fibres of the external capsule as they pass medially towards the subthalamic region (p. 1014), the tail of the caudate nucleus and the stria semicircularis (stria terminalis). More anteriorly, it is separated from the amygdaloid nucleus by the ansa peduncularis (p. 957).

Structure.—The caudate nucleus and the putamen of the lentiform nucleus are very similar in their histological features, and both differ very conspicuously from the globus pallidus. Their constituent nerve-cells are small and they show a poverty of nerve-fibres, those that are present forming a finely medullated plexus. The globus pallidus on the other hand is characterised by the possession of large cells, not unlike the motor cells of the anterior grey column of the spinal cord. In addition, it is rich in medullated fibres, which are visible to the unaided eye where they form the external and internal medullary laminæ. The external lamina separates the globus pallidus from the putamen, and the internal lamina subdivides it into a larger lateral and a smaller medial portion (fig. 917).

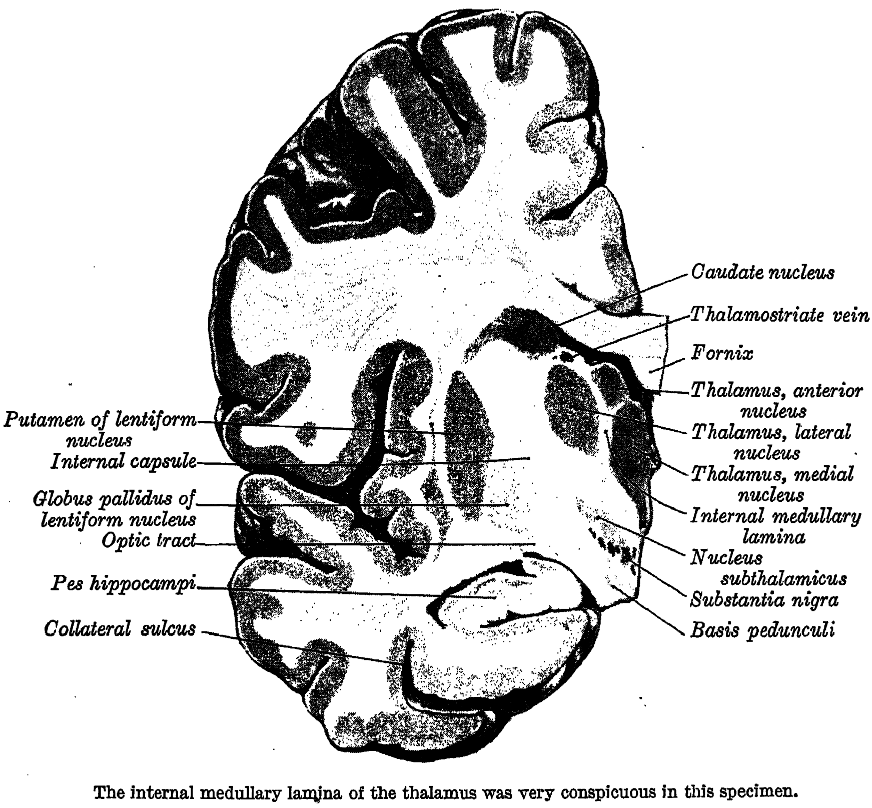
Connexions.—*Afferent fibres* reach the corpus striatum from the thalamus and are distributed to the caudate nucleus, the putamen, and, probably, the globus pallidus. There is no clear evidence that cortical fibres either terminate

in, or give collaterals to the corpus striatum, and it would appear that the thalamus is the principal source of supply.

The *efferent fibres* all arise in the globus pallidus, and they pass through the internal capsule to reach (1) the thalamus, (2) the hypothalamus and (3) the red nucleus. They possess medullated sheaths, but they can be distinguished from the fibres of the internal capsule by their smaller size. Many of these fibres appear on the inferior aspect of the globus pallidus and pass medially, constituting the *ansa lenticularis*.

Internuncial fibres connect the caudate nucleus and the putamen to each other and to the globus pallidus. They are finely medullated, and in the globus pallidus are responsible for the medullary laminæ.

FIG. 917.—A coronal section through the right cerebral hemisphere. Anterior aspect.



The internal medullary lamina of the thalamus was very conspicuous in this specimen.

Functional significance of the corpus striatum.—The palæostriatum of fishes, which corresponds to the globus pallidus in man, receives its afferent fibres from the olfactory pathways, and its efferent fibres establish connexions with the motor centres in the brain-stem and the spinal cord. There is no doubt that it functions as a higher motor centre, enabling olfactory impressions to exert a preponderating influence on the animal's movements. The addition of the neostriatum in the reptilian brain is, as has been seen (p. 972), synchronous with the passage into the telencephalon of new fibres of thalamic origin, and it has been suggested that, owing to the presence of the neostriatum and its connexions with both the thalamus and the palæostriatum, visual, tactile and other impressions are able to modify the responses which would otherwise result from olfactory stimuli.

It is clear that the evolution of the neopallium and the process of telencephalisation have relegated the corpus striatum to a subsidiary role. Despite the intimate topographical relationship between it and the insula, no fibre connexions have been shown to exist between it and the cerebral cortex. Kappers is of opinion that the corpus striatum in the mammalian brain is

associated with the sympathetic nervous system, but this view receives little support from clinical evidence. Experimental evidence is largely of a negative character. Ramsay Hunt, Kinnier Wilson and others have investigated cases of degeneration and atrophy of the corpus striatum. Rigidity, which is due to hypertonicity, and tremor, which is independent of the rigidity, are constant features, whether the neostriatum or the globus pallidus is affected. This evidence points to the association of the corpus striatum with the motor apparatus. Ramsay Hunt finds that automatic associated movements are lost when the globus pallidus is involved and that they are increased and accompanied by uncontrolled athetoid * movements when the disease affects the neostriatum only. It must be confessed, however, that very little definite knowledge is available concerning the functional significance of the large nuclear mass formed by the caudate and lentiform nuclei.

The **amygdaloid nucleus** is a mass of grey substance which is situated in the anterior end of the roof of the inferior horn of the lateral ventricle. Anteriorly and superiorly it is continuous with the grey matter of the piriform area and the anterior perforated substance, respectively. Posteriorly it is continuous with the tail of the caudate nucleus. It receives afferent fibres from the olfactory pathway, probably secondary olfactory neurones, and sends its efferent fibres backwards in the roof of the inferior horn as the stria semicircularis (stria terminalis).

The amygdaloid nucleus represents the archistriatum, which is differentiated in the reptilian brain prior to the neostriatum. Its precise functional significance is obscure.

The *stria semicircularis* (stria terminalis) is a small collection of medullated nerve-fibres which issues from the posterior end of the amygdaloid nucleus and runs backwards in the roof of the inferior horn of the lateral ventricle on the medial side of the tail of the caudate nucleus. It follows the curve of the nucleus and runs forwards in the floor of the body of the ventricle, occupying the groove which separates the caudate nucleus from the thalamus. Below the interventricular foramen it gives off some fibres to the anterior commissure and turns downwards to enter the hypothalamus, where it ends by sending fibres to several of the hypothalamic nuclei. It may therefore be regarded as a pathway for the association of olfactory and visceral stimuli.

The **claustrum** is a thin sheet of grey matter, co-extensive with the insula and the putamen of the lentiform nucleus, from which it is separated by the fibres of the external capsule. It is thickest below and in front, where it becomes continuous with the anterior perforated substance. Regarded by some authorities as belonging to the corpus striatum and by others as a detached portion of the insular cortex, it is undoubtedly of cortical origin, but its connexions and functions are quite unknown.

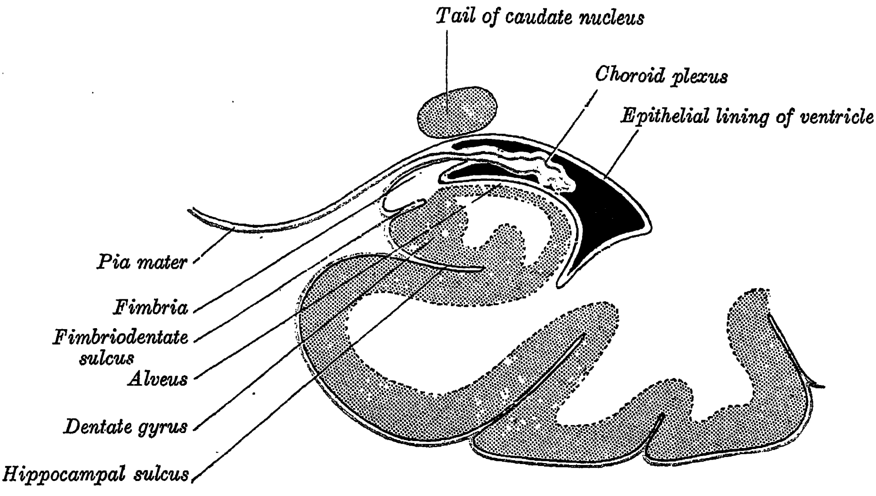
The **external capsule** is a thin layer of white matter which is interposed between the lateral aspect of the lentiform nucleus and the claustrum. According to Meynert the fibres of the external capsule are derived from the fronto-parietal operculum of the insula and, after passing across the lateral surface of the lentiform nucleus, they turn medially below the nucleus and the ansa lenticularis. Their subthalamic connexions are uncertain. Some of the fibres of the anterior commissure are believed to traverse the external capsule.

The choroidal fissure and the choroid plexus of the lateral ventricle.—The *choroid plexus* of the lateral ventricle is a highly vascular fringe of pia mater which projects into the ventricular cavity, invaginating the ependymal medial wall of the ventricle before it and receiving from it a complete investment (fig. 885). It extends as far forwards as the interventricular foramen, where it is continuous with the corresponding plexus of the opposite side. Posteriorly it is carried round the posterior end of the thalamus into the inferior horn as far as the pes hippocampi. The ependyma which covers the choroid plexus is an infolded part of the medial wall of the hemisphere, and this infolding constitutes the *choroidal fissure*. The lips of the fissure are the lateral edge of the fornix and the upper surface of the thalamus, in the body of the ventricle (fig. 885), and the edge of the fimbria and the stria semicircularis (stria terminalis) in the inferior horn (fig. 918). The two parts of the fissure

* The term 'athetoid movements' is used to describe repeated, deliberate movements of a purposeless character.

are directly continuous with each other round the posterior end of the thalamus. It will be remembered that the choroidal fissure is the first fissure to appear on the surface of the hemisphere (p. 118), and coronal sections across the brain of a two-months' embryo show that the floor of the upper part of the fissure is directly continuous with the ependymal roof of the third ventricle, and that the vascular pia mater which covers the latter is continued into the choroidal fissure on each side. At this stage, and prior to the development of the commissures and the expansion of the lamina terminalis, only one layer of pia mater covers the roof of the third ventricle (fig. 152). When the corpus callosum grows backwards, it passes above the line of the choroidal fissure and carries with it on its under surface a second layer of pia mater (fig. 884). In this way two layers of pia mater come to lie above the ependymal roof of the third ventricle and on each side they pass into the choroidal fissure to enclose the vessels of the choroid plexus (fig. 885). Posteriorly these two layers separate from each other. The lower layer follows the roof of the third ventricle to

FIG. 918.—A coronal section through the inferior horn of the lateral ventricle. Diagrammatic.



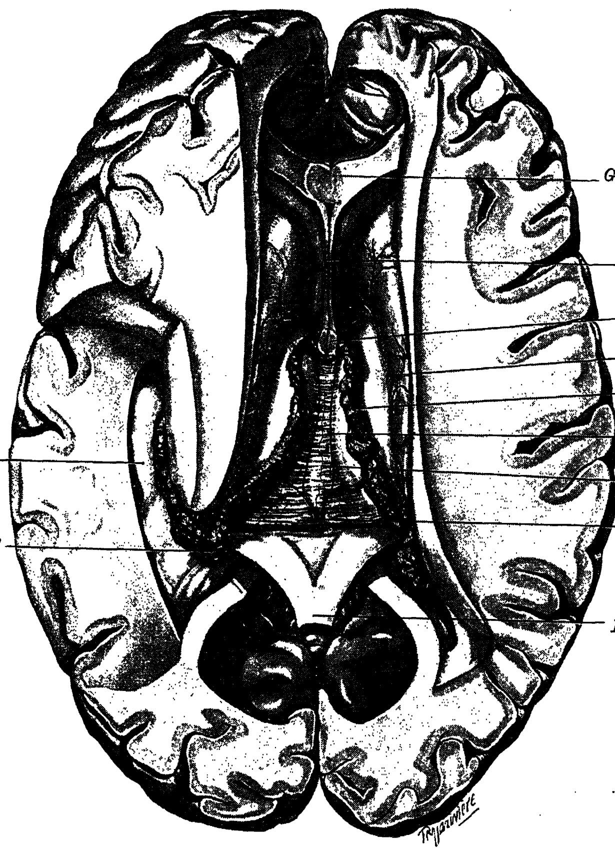
the pineal body and the tectum of the mid-brain, while the upper layer ascends on the back of the splenium and is continuous with the pia mater on the upper surface of the corpus callosum (fig. 884).

These two layers of pia mater constitute the *tela chorioidea of the third ventricle.* Viewed from above, they form a triangular fold, the rounded apex being situated at the interventricular foramen (fig. 919). The edges are irregular and contain the vascular fringes of the choroid plexuses of the lateral ventricles. The posterior or basal angles are continuous with the vascular fringes of pia mater which are invaginated into the inferior horns, but over the central and wider part of the base the two constituent layers separate from each other as already explained. When the splenium of the corpus callosum is viewed from behind, a transverse slit is seen below it. This slit is termed the *transverse fissure* of the brain, but it must be remembered that it is not really a cerebral fissure in the true sense of the term, for it does not correspond to any infolding of the cerebral cortex. Before the pia mater is removed, the transverse fissure leads into the interval between the two layers of the tela chorioidea, and this interval is a portion of the extra-cerebral space which has been enclosed by the backward growth of the corpus callosum.

The choroid plexus consists of minute and highly vascular villous processes, each possessing an afferent and an efferent blood-vessel. The *arteries* of the plexus are: (*a*) the anterior choroid artery, a branch of the internal carotid artery, which enters the plexus at the anterior end of the inferior horn; and (*b*) the posterior choroid, one or two small branches of the posterior cerebral artery, which pass into the upper part of the choroidal fissure. The *veins* of the plexus unite to form a single tortuous vessel (choroid vein) which begins

in the inferior horn of the ventricle and courses in the plexus to the interventricular foramen and there joins the thalamostriate vein (p. 814) to form the corresponding *internal cerebral vein*. The two internal cerebral veins run backwards close to the median plane between the two layers of the tela chorioidea of the third ventricle. When the two layers separate below the splenium of the corpus callosum, the two veins unite to form the *great cerebral vein*, which curves backwards and upwards behind the splenium to join the straight sinus.

FIG. 919.—The tela chorioidea of the third ventricle and the choroid plexus of the lateral ventricle.



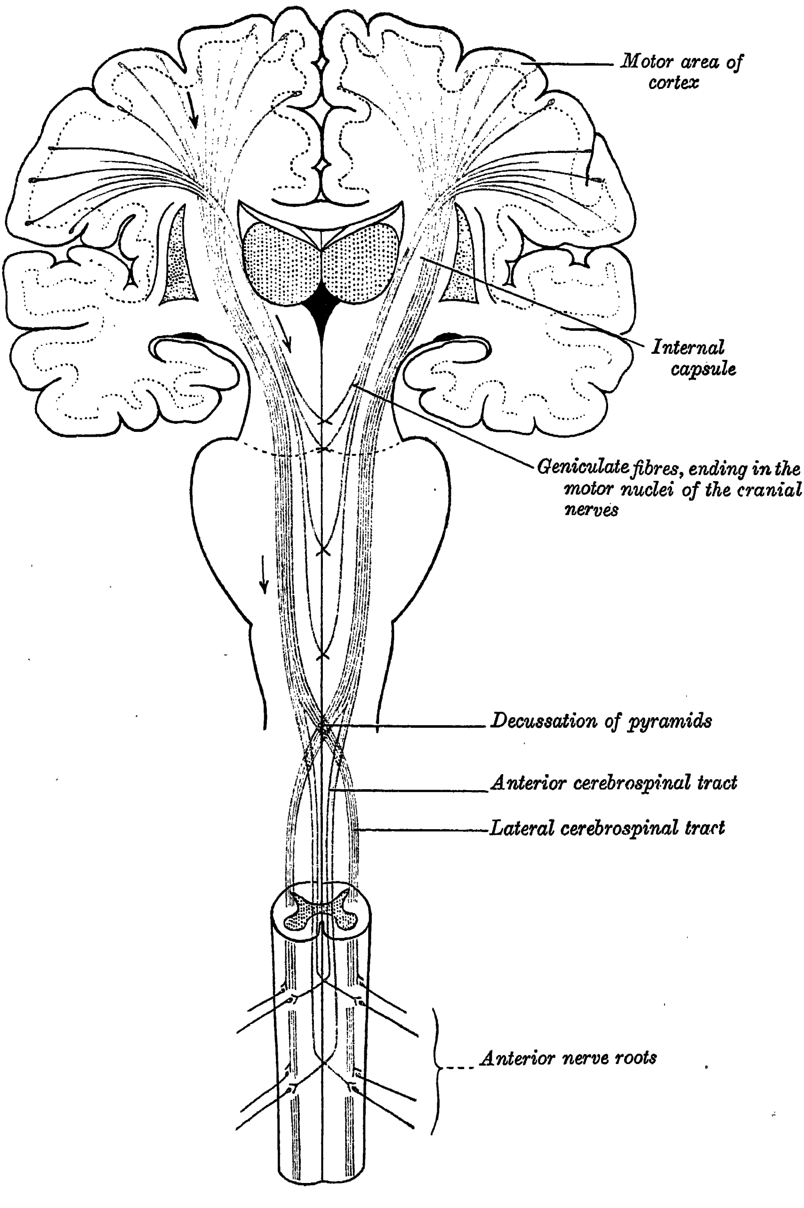
The trunk of the corpus callosum has been removed and the body of the fornix has been cut across anteriorly and turned backwards.

The weight of the brain.—The average weight of the brain, in the adult male, is about 1380 gms.; that of the female, about 1250 gms. In the male, the maximum weight out of 278 cases was 1840 gms. and the minimum weight 964 gms. The maximum weight of the adult female brain, out of 191 cases, was 1585 gms. and the minimum weight 879 gms. The brain increases rapidly during the first twelve months of life, and the brain of a year-old child is on the average two and a half times as heavy as the brain of a newly-born infant. By the sixth year the brain has reached 85 per cent. or more of its weight in the adult. This increase is attributable to the medullation of the nerve-fibres. As age advances, the brain decreases slowly in weight; in old age the decrease takes place more rapidly, and may amount to about 28 gms.

Applied Anatomy.—The *internal capsule* is often the seat of hæmorrhage from the lateral striate artery (Charcot's 'artery of cerebral hæmorrhage'), or of thrombosis, in patients whose vessels are weakened by old age or disease. A 'stroke,' or 'apoplexy,'

is the result; blood is effused from the ruptured vessels and tears up the surrounding brain tissue, and also interferes with the neighbouring fibres by the compression set up by its mass. If the hæmorrhage is sudden and at all large, rapid and complete loss of consciousness follows, with paralysis of the opposite side of the body and loss of control over the sphincters, together with a variable degree of hemianæsthesia. If it is the posterior

FIG. 920.—The principal motor tracts. (Modified from Poirier.)



limb of the internal capsule that is involved, the paralysis will be more marked in the leg than in the arm, and will be associated with homonymous hemianopia or blindness of the corresponding halves of the two retinæ, the patient being unable to see objects on the opposite side of the body.

THE CHIEF NERVE TRACTS

The anatomy of the various parts of the central nervous system having been described, a short summary will now be given of the chief ascending and descending nerve tracts connecting the brain and the spinal cord. This may be effected most conveniently by grouping them as follows: (*a*) the motor (descending) tracts, (*b*) the sensory (ascending) tracts, and (*c*) the cerebellar systems (ascending and descending).

The Motor Tracts

Included under this heading are (*a*) the principal motor tracts, originating in the cerebral cortex, and (*b*) the secondary motor tracts originating in the basal nuclei.

The principal motor tracts (fig. 920).—The constituent fibres of these tracts are the axis-cylinder processes of the cells of Betz situated in the motor area of the cortex. The fibres converge as they descend through the corona radiata, and pass between the lentiform nucleus and thalamus, in the genu and in the anterior two-thirds of the posterior limb of the internal capsule; those in the genu are named the geniculate fibres, the others the cerebrospinal fibres. Both sets of fibres proceed downwards, through the middle three-fifths of the base of the cerebral peduncle, and then the geniculate fibres cross the median plane, and end by arborising around the cells of the motor nuclei of the cranial nerves. The cerebrospinal fibres are continued downwards into the pyramid of the medulla oblongata, and thence proceed by two paths. The fibres nearest to the anterior median fissure cross the median plane, intersecting the corresponding fibres from the opposite side and forming the *decussation of the pyramids*, and descend in the lateral white column of the opposite side of the spinal cord, as the lateral cerebrospinal fasciculus (crossed pyramidal tract). Throughout the length of the spinal cord, fibres from this tract pass into the grey matter, to end by arborising around cells of the anterior horn, or (according to Sharpey-Schafer, p. 899) by arborising around cells of the posterior horn. The more laterally placed cerebrospinal fibres do not decussate in the medulla oblongata, but descend as the anterior cerebrospinal fasciculus (direct pyramidal tract); in each segment of the upper half of the spinal cord some of these fibres cross in the anterior white commissure, with the result that all end in the grey matter of the opposite side. There is considerable variation in the extent to which decussation takes place in the medulla oblongata; about two-thirds or three-fourths of the cerebrospinal fibres usually decussate in the medulla oblongata and the remainder in the spinal cord.

The secondary motor tracts.—While the presence of a motor path distinct from the principal motor tracts has for some time been surmised on clinical grounds, it is only recently that anatomical details of it have become available, and many of these are still under investigation. In this summary it will be sufficient to indicate that the chief nuclei on the efferent pathway are the globus pallidus of the corpus striatum and the red nucleus of the mid-brain. The main pathway is from the globus pallidus to the red nucleus, and thence to the opposite side of the spinal cord by the rubrospinal tract. Subsidiary pathways begin in the globus pallidus and run to the subthalamic nucleus and formatio reticularis, and proceed by successive neurones downwards to the spinal cord. All these descending fibres ultimately reach and arborise round the motor cells of the cranial nerve nuclei or of the anterior grey column of the spinal cord. These pathways are, for the most part, entirely independent of the cerebral cortex, and are activated through the substantia nigra, the thalamus and the hypothalamus. All the tracts concerned are often grouped together under the term, the *extrapyramidal system*.

The axons of the motor cells in the cranial nuclei proceed through the cranial nerves, while those of the cells in the anterior grey column of the spinal cord pass out in the anterior roots of the spinal nerves, forming thus in each instance a *final common motor pathway*, along which impulses are conducted to the muscles of the head, trunk and limbs. For clinical purposes the neurones constituting the final motor pathway are grouped as the *lower motor neurones*, while the other neurones of the motor pathway form the group of *upper motor neurones*.

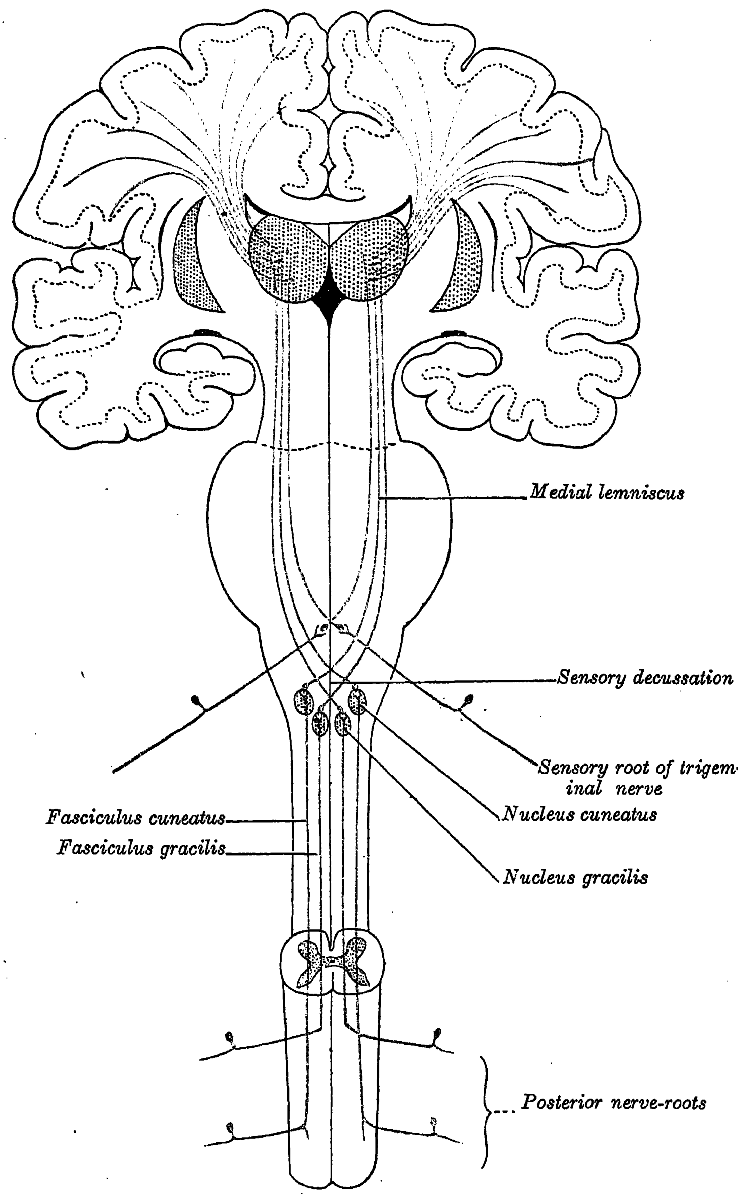
The Sensory Tracts

The sensory impulses traversing the cerebrospinal axis may be resolved into the following groups: (1) *interoceptive*, arising in the viscera; (2) *proprioceptive*, arising in the muscles, tendons, joints, etc.; and (3) *exteroceptive*, initiated on the surface of the body. Exteroceptive sensibility may be subdivided into a cruder (protopathic), and a finer, discriminative variety.

(1) Little is known concerning the pathway followed by the interoceptive fibres. (2) The proprioceptive fibres are accompanied throughout by the fibres which convey the discriminative variety of exteroceptive sensibility (p. 883). They enter the spinal cord through the posterior roots of the spinal nerves, and at once divide into descending and ascending branches; the descending branches soon enter and ramify in the grey matter; the majority of the ascending branches are continued into the posterior white columns, where they join the fasciculus gracilis and fasciculus cuneatus. These fasciculi end by arborising around the cells of the nucleus gracilis and nucleus cuneatus in the medulla oblongata (fig. 921), and from these cells the fibres of the medial lemniscus take origin and cross to the opposite side in the sensory decussation. In its further course the medial lemniscus receives fibres from the terminal nuclei of the ordinary sensory cranial nerves of the

opposite side. Ascending through the cerebral peduncle the medial lemniscus is carried into the thalamus, where its fibres end. From the cells of the thalamus the fibres of the third link in the chain arise and pass to the cerebral cortex behind the central sulcus. It is important to observe that these fibres do not cross the median plane until they reach the medulla oblongata, and, therefore, unilateral lesions of the spinal cord involving the post-

FIG. 921.—The pathway of the fibres conveying proprioceptive and discriminative sensibility. (Modified from Poirier.)



erior white column, are accompanied by *homolateral* loss of proprioceptive and discriminative sensibility.

(3) Fibres conveying the cruder type of exteroceptive sensibility ascend through two pathways in the spinal cord. (*a*) *Fibres conveying painful and thermal stimuli* are relayed in the substantia gelatinosa and the adjoining head of the posterior grey column and *cross the median plane at or a little above the level at which they enter the spinal cord.* They then join the lateral spinothalamic tract. (*b*) *Fibres conveying tactile and pressure stimuli* are relayed in the head of the posterior grey column and then ascend for a varying number of segments

before they cross the median plane and pass into the anterior spinothalamic tract.* Both spinothalamic tracts ascend through the spinal medulla to the medulla oblongata, where they meet and form the *spinal lemniscus*. At a slightly higher level they are joined by the *trigeminal lemniscus*, which conveys the same varieties of sensibility from the trigeminal area. In its course through the pons and mid-brain, the spinal lemniscus is closely related to the medial lemniscus and it terminates above in the lateral nucleus of the thalamus. There the fibres are relayed and the fibres of the third neurones pass through the posterior limb of the internal capsule to reach the postcentral gyrus.

It is important to observe that the fibres conveying painful and thermal sensations cross the median plane soon after entering the spinal cord. Unilateral lesions of the spinothalamic tracts are accompanied by contralateral loss of painful and thermal sensibility. Lesions in the neighbourhood of the commissural grey matter, on the other hand, will cause bilateral loss of both forms of sensibility, but the areas affected will correspond to the segments involved in the spinal cord.

It will be observed that in most cases there are three cell-stations interposed in the course of the sensory impulses; for clinical purposes, therefore, three groups of neurones are recognised: (1) the *lowest sensory neurones*, which comprise the cells of the posterior root ganglia, and their peripheral and central processes; (2) the *intermediate sensory neurones* between these and the thalamus; and (3) the *highest sensory neurones*, which are the cells of the thalamus and the fibres passing from them to the cerebral cortex.

The Cerebellar Systems

The cerebellum exercises such an important influence on muscle tone (p. 937) that impulses must be able to reach it from all parts of the cerebral cortex as well as from the spinal cord, while impulses are conveyed from it to other co-ordinating and motor nuclei in the cerebrospinal axis. Only the larger tracts can be summarised here.

Afferent tracts.—A considerable number of afferent impulses reach the cerebellum by way of the spinal cord through the fibres of the posterior nerve-roots. In the spinal cord there are three main pathways. The entering fibres may end around the cells of the thoracic nucleus; the fibres from these cells form the posterior spinocerebellar tract of the same side, and are carried up to the medulla oblongata, where they enter the inferior cerebellar peduncle and are conveyed to the cortex of the vermis of the cerebellum. A second group of entering fibres arborises around the cells of the posterior grey column of the spinal cord; of the fibres of these cells some cross to the opposite side while others pass up the same side, forming an anterior spinocerebellar tract, which traverses the spinal cord on the surface of the lateral white column, runs through the medulla oblongata and pons, and then turns downwards and backwards to reach the cortex of the vermis by way of the superior cerebellar peduncle. The third group of entering fibres runs up in the fasciculus gracilis and fasciculus cuneatus, and ends in the nucleus gracilis and nucleus cuneatus; relayed there, the fibres pass in the inferior cerebellar peduncle to reach the cerebellar cortex.

Three important afferent tracts to the cerebellum run from the brain-stem, viz. the vestibulocerebellar, the olivocerebellar and the tectocerebellar. The vestibulocerebellar tract arises from the vestibular nuclei in the floor of the fourth ventricle, and runs in the inferior cerebellar peduncle to the cerebellar cortex. The olivocerebellar tract arises in the olivary nucleus, crosses the median plane, and gains the cerebellum through the inferior cerebellar peduncle. The tectocerebellar tract has its origin in the cells of the corpora quadrigemina and enters the cerebellum through the superior cerebellar peduncle.

Of the remaining afferent fibres to the cerebellum the most important group is that of the cerebro-ponto-cerebellar tracts. These fibres arise from cells of the cerebral cortex, travel downwards through the internal capsule and cerebral peduncle, and end by arborising round the cells of the nuclei pontis. New fibres arise from the cells of these nuclei, cross the median plane, pass through the middle cerebellar peduncle, and end in the cortex of the cerebellar hemispheres.

Efferent tracts.—The efferent tracts from the cerebellar cortex originate from the Purkinje cells and run to arborise around cells of the cerebellar nuclei; with the possible exception of the flocculus, no fibres pass directly from the cerebellar cortex to the rest of the brain or to the spinal cord. Several small groups of fibres arising from the cerebellar nuclei run to various nuclei in the cerebrospinal axis, but the chief efferent tract is that which forms the greater part of the superior cerebellar peduncle, crosses the median plane, and runs mainly to the red nucleus, giving some fibres to the thalamus. From the red nucleus the rubrospinal tract arises, crosses to the opposite side, and travels down in the pons and medulla oblongata to the lateral white column of the spinal cord, where it ultimately ends around the motor cells in the anterior grey column.

Other efferent fibres from the cerebellar nuclei pass to the nuclei of the vestibular nerve, and are relayed to the spinal cord in the vestibulospinal tract.

* It should be stated that, whereas the evidence for the existence of the lateral spinothalamic tract is full and convincing, the evidence for the existence of the anterior spinothalamic tract is by no means complete.

AFFERENT PATHWAYS OF SPINAL CORD

EXTEROCEPTIVE SENSIBILITY.

- (*a*) Crude
  - (1) Pain and Temperature → Substantia Gelatinosa → Cross at once → Lateral Spino-thalamic Tract
  - [(2) Touch and Pressure → Posterior Horn → Cross two or three segments higher → Anterior Spinothalamic Tract]
  - → Spinal Lemniscus (Fillet) → Thalamus → Postcentral Gyrus
- (*b*) Discriminative (except Temperature Discrimination) → Posterior white Column (Uncrossed and Unrelayed) → Nucleus Gracilis and Cuneatus → Internal Arcuate Fibres → Decussation of Lemnisci (Fillets) → Medial Lemniscus (Fillet) → Thalamus → Postcentral Gyrus

PROPRIOCEPTIVE SENSIBILITY.

- (*a*) Conscious (Postural sense) → Posterior white Column (Uncrossed and Unrelayed) → Nucleus Gracilis and Cuneatus → Internal Arcuate Fibres → Decussation of Lemnisci (Fillets) → Medial Lemniscus (Fillet) → Thalamus → Postcentral Gyrus
- (*b*) Unconscious
  - (1) (Adjustments of muscle tone to ensure perfect co-ordination and synergic action) → Posterior white Column → External Arcuate Fibres → viâ Inf. Cerebellar Peduncles (Crossed and Uncrossed) → Cerebellum (? Neocerebellum)
  - (2) (as 1) → Nucleus Thoracicus → Uncrossed → Posterior Spino-cerebellar Tract → Inf. Cerebellar Peduncle → Cerebellum (Vermis)
  - and
  - (3) (as 1) → Nucleus Thoracicus → Crossed and Uncrossed → Ant. Spino-cerebellar Tract → Sup. Cerebellar Peduncles → Cerebellum (Vermis)
  - (4) Spinovisual Reflexes → Post. Horn → Cross early → Spinotectal Tract → Superior Corpus Quadrigeminum

INTEROCEPTIVE SENSIBILITY. → (?) Ascending relays in Intersegmental Tracts

Myelination of the Fibre Groups of the Spinal Cord and Brain-stem

According to Lucas Keene and Hewer * the process of myelination in the spinal cord and the brain-stem occurs in four distinct stages. During the fourteenth week of intra-uterine life myelination commences in the anterior and posterior roots of the spinal nerves, in all the cranial nerves (with the exceptions of the optic, the cochlear and the sensory part of the trigeminal nerve (p. 1035) and in many of the tracts. Between the twenty-second and the twenty-fourth weeks additional fibre groups become affected. The process receives a fresh impetus at or just before birth and again about eight months later.

Depending on the number and on the length of the fibres involved, the period over which the process extends may last for from two to ten weeks or more.

The tracts become myelinated in the following order:

In the first period: (1) fasciculus cuneatus, (2) posterior spinocerebellar, (3) anterior spinocerebellar, (4) lateral spinothalamic, (5) spinotectal, (6) anterior intersegmental and (7) the medial longitudinal bundle.

In the second period: (1) fasciculus gracilis, (2) posterior intersegmental, (3) lateral intersegmental, (4) medial lemniscus, (5) olivocerebellar and (6) fasciculus retroflexus.

In the third period: (1) posterolateral, (2) lateral cerebrospinal (crossed pyramidal), (3) rubrospinal, (4) anterior cerebrospinal (direct pyramidal), (5) external arcuate fibres, (6) ponticerebellar fibres and (7) corticipontine fibres.

In the fourth period: the bulbospinal tract (p. 900).

Applied Anatomy.—The chief symptoms of diseases of the brain and spinal cord depend upon the particular systems of neurones picked out for attack, and some of them may be briefly summarised as follows. *Motor paralysis* of the *spastic* type, with rigidity of the muscles and increased reflexes, follows destruction of the upper motor neurones; *flaccid* paralysis, with loss of the reflexes and rapid muscular atrophy, follows destruction of the lower motor neurones. *Sensory paralysis* follows injury to any part of the sensory path; in tabes it is due to injury of the lowest sensory neurones, in hemiplegia to destruction of the highest sensory axon as it traverses the posterior limb of the internal capsule. *Dissociation of sensations,* or the loss of some forms of sensation while others remain unimpaired, is seen in a number of conditions such as tabes and syringomyelia; it shows that the paths through which various forms of sensation travel to the brain are different. *Abnormalities of reflex actions* are of very great help in the diagnosis of nervous complaints. The numerous *superficial or skin reflexes* (e.g. the plantar, tickling the sole of the foot brings on plantar flexion of the toes), if present, show that the reflex arcs on whose integrity their existence depends are intact; but they are often absent in health and so cannot be trusted to indicate disease. The *deep reflexes or tendon reactions,* such as the knee-jerk, or the tendo calcaneus jerk, are increased in chronic degeneration of, or gradually increasing pressure on, the cerebrospinal fibres (upper motor neurone). They are lost when the lower motor or lower sensory neurones are diseased, and in a few other conditions; absence of the knee-jerk is very rare in health, and suggests disease in some part of its reflex arc, in the third and fourth lumbar segments of the cord, or else, more rarely, grave intracranial or spinal disease cutting off the lower from the higher nervous centres. The *organic reflexes* of the pupil, bladder, and rectum are of the greatest practical importance. The commonest defect in the reflexes of the pupil is reflex iridoplegia, or failure to contract on exposure to light, without failure to contract on convergence or accommodation (' Argyll Robertson ' pupil). The pupil is also contracted (miosis), and may or may not dilate when the skin of the neck is pinched (the ciliospinal reflex). Micturition is a spinal reflex much under the control of the brain; if the centre for micturition in the second sacral segment is destroyed the sphincter and the walls of the bladder are paralysed, the bladder becomes distended with urine, and incontinence from overflow results. If this centre escapes injury but is cut off more or less completely from impulses descending to it from above there will be more or less interference with micturition. This varies in degree from the ' precipitate micturition ' of tabetic patients, who must perforce hurry to pass water the moment the impulse seizes them, to the state of ' reflex incontinence,' when the bladder automatically empties itself from time to time, almost without the patient's knowledge. Defæcation is a very similar spinal reflex, and is liable to very similar disorders of function.

The *upper motor neurone* (p. 1018) is affected in hemiplegia, the *lower motor neurone* (p. 1018) in infantile spinal paralysis; both these systems of neurones are diseased together in the somewhat rare disorders known as amyotrophic lateral sclerosis and progressive muscular atrophy. The chief symptom here is wasting and weakness in certain groups of muscles; the palsy will be flaccid, with loss of the reflexes, or spastic, with increased reflexes, according as the degeneration mainly involves the lower or the upper motor neurone. The sphincters are affected only in the later stages of these diseases.

Pathological changes in the *lowest sensory neurone* are the cause of tabes dorsalis or locomotor ataxy, which occurs almost entirely in adults who have had syphilis. In the

* M. F. Lucas Keene and E. E. Hewer, *Journal of Anatomy,* vol. lxvi. 1931.

early or pre-ataxic stage the patient may exhibit the Argyll Robertson pupil (see above) and loss of knee-jerks, and complain of sharp, stabbing pains ('lightning pains') in the limbs, difficult or precipitate micturition, and sometimes of severe and painful attacks of indigestion (gastric crises). In the second or ataxic stage, coming on perhaps years later, he will complain, in addition, of interference with his powers of getting about and turning, although his muscular strength is well preserved. He is unable to stand steady with his eyes shut or in the dark, his gait becomes exaggerated and stamping in character, he has to use a stout stick to walk with, and he may suffer from painful crises in various parts of the body. Control over the sphincters is further weakened, and on examination there will be found marked incoordination of the limbs, zones of anæsthesia about the trunk or down the limbs, and marked analgesia (or insensitiveness to pain) when pressure is applied to the bones, tendons, trachea, tongue, eyeballs, mammæ and testes.*

THE MEMBRANES OF THE BRAIN AND SPINAL CORD

The brain and the spinal cord are enveloped by three membranes [meninges], named from without inwards: the dura mater, the arachnoid mater and the pia mater.

The Dura Mater

The **dura mater** is a thick and dense inelastic membrane. The portion of it which encloses the brain (cerebral dura mater) differs in several particulars from that which surrounds the spinal cord (spinal dura mater), and therefore it is necessary to describe them separately; the two parts, however, form one complete membrane, and are continuous with each other at the foramen magnum.

The **cerebral dura mater** lines the interior of the skull, and serves the twofold purpose of an internal periosteum to the bones, and a protective membrane for the brain. It is composed of two layers, an inner or meningeal and an outer or endosteal; these are closely united, except along certain lines where they are separated by the venous sinuses which drain the blood from the brain (p. 814). The dura mater adheres to the inner surfaces of the cranial bones, and sends blood-vessels and fibrous processes into them, the adhesion being most marked at the sutures, at the base of the skull, and around the foramen magnum. The blood-vessels and fibrous processes are torn across when the dura mater is detached from the bones, and consequently the outer surface of the membrane presents a rough and fibrillated appearance; the inner surface is smooth and lined by a layer of mesothelium. The dura mater is continuous through the sutures with the pericranium, and through the superior orbital fissure with the periosteal lining of the orbital cavity. It provides tubular sheaths for the cranial nerves as the latter pass through the foramina at the base of the skull; outside the skull these sheaths fuse with the epineurium of the nerves; the sheath of the optic nerve is continuous with the sclera of the eyeball.

The cerebral dura mater sends inwards four processes or septa which divide the cranial cavity into a series of freely communicating spaces for the lodgment of the subdivisions of the brain. These processes are named the falx cerebri, the tentorium cerebelli, the falx cerebelli and the diaphragma sellæ. They are covered on their free surfaces by mesothelium, and they contain a variable quantity of white fibrous and yellow elastic tissue.

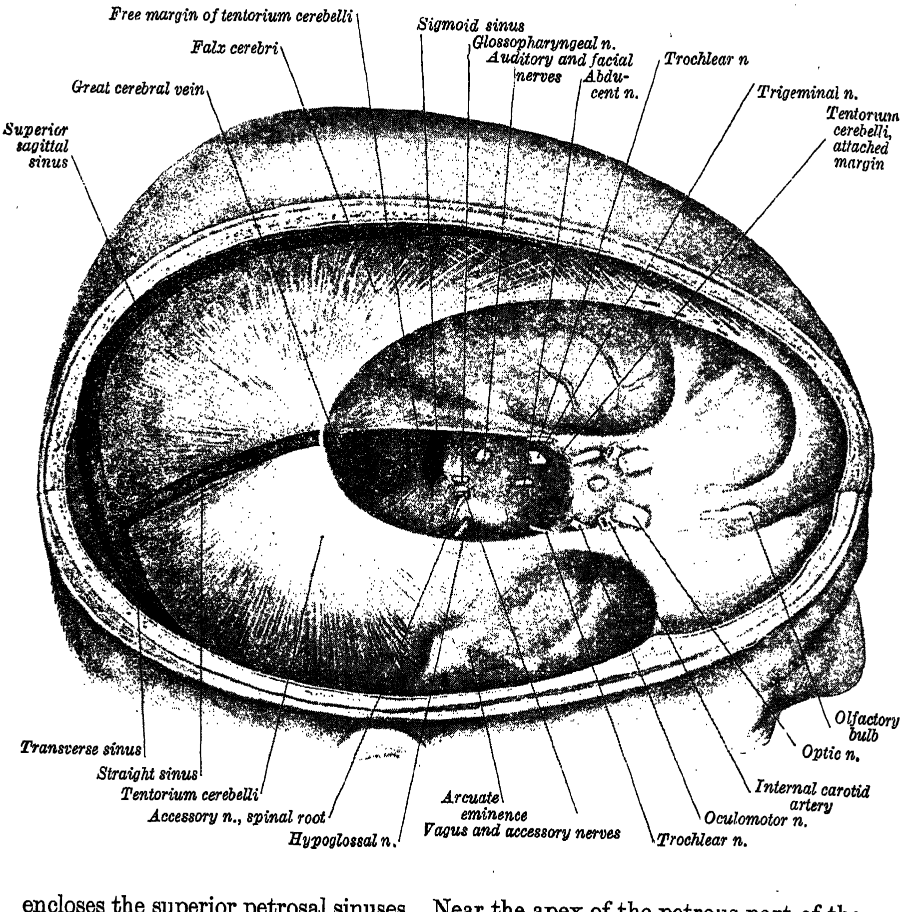
The *falx cerebri* (fig. 922), so named from its sickle-like form, is a strong, arched process of dura mater which descends vertically in the longitudinal fissure between the cerebral hemispheres. It is narrow in front, where it is fixed to the crista galli of the ethmoid bone; and broad behind, where it is attached in the median plane to the upper surface of the tentorium cerebelli; the narrow, anterior part is thin, and is frequently perforated by numerous apertures. The upper margin of the falx cerebri is convex, and attached to the inner surface of the skull on each side of the median plane, as far back as the internal occipital protuberance; the superior sagittal sinus runs along this

* J. Grasset, *Le Tabes, Maladie de la Sensibilité profonde*; Montpellier, 1909.

margin. Its lower margin is free and concave, and contains the inferior sagittal sinus. The straight sinus runs along its attachment to the tentorium cerebelli.

The *tentorium cerebelli* (fig. 923) is a crescentic, arched lamina of dura mater which covers the cerebellum, and supports the occipital lobes of the cerebrum. Its concave, anterior border is free, and between it and the dorsum sellæ of the sphenoid bone there is a large oval opening, named the *tentorial notch*, which is occupied by the mid-brain. Its convex border is attached (*a*) posteriorly, to the lips of the transverse sulci of the occipital bone and the postero-inferior angles of the parietal bones, and lodges the transverse sinuses; (*b*) laterally, to the superior borders of the petrous parts of the temporal bones, where it

FIG. 922.—The dura mater and its processes. Exposed by the removal of a part of the right half of the skull, and the brain.



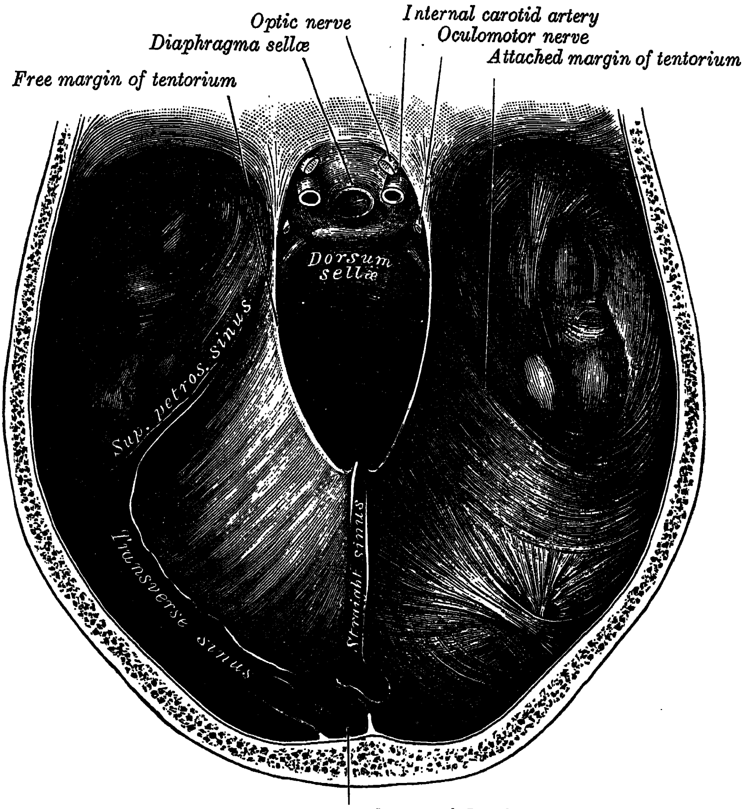
encloses the superior petrosal sinuses. Near the apex of the petrous part of the temporal bone the lower layer of the tentorium is carried forwards and laterally, below the superior petrosal sinus and the dura mater in the floor of the middle cranial fossa, to form the roof of the recess in which the trigeminal (semilunar) ganglion and the adjoining parts of the roots and divisions of the trigeminal nerve are lodged. This little recess is termed the *cavum trigeminale*. Lateral to the ganglion, its roof becomes reflected on to the trigeminal impression on the apex of the petrous part of the temporal bone and so becomes continuous with the dura mater on the posterior aspect of that bone. Anteriorly the recess comes into relation with, and projects into, the cavernous sinus, up which it extends for at least one-half of its height.* The lateral wall of the recess is adherent to the deep surface of the dura mater which forms the lateral wall of the cavernous sinus. At the apex of the petrous part of the temporal bone the

* R. D. Lockhart, *Journal of Anatomy*, vol. lxii. 1927.

free and attached borders of the tentorium cross each other ; the free borders are fixed to the anterior, and the attached borders to the posterior, clinoid processes of the sphenoid bone. As already described, the straight sinus runs in the line of attachment of the posterior part of the inferior border of the falx cerebri to the tentorium cerebelli.

The *falx cerebelli* is a small, sickle-shaped process of dura mater which is situated below the tentorium cerebelli, and projects forwards into the posterior cerebellar notch. Its base, directed upwards, is attached to the posterior part of the inferior surface of the tentorium cerebelli, in the median plane ; its posterior margin contains the occipital sinus, and is fixed to the internal occipital

Fig. 923.—The tentorium cerebelli. Superior surface.



crest ; its apex frequently divides into two small folds, which are lost on the sides of the foramen magnum.

The *diaphragma sellæ* (fig. 923) is a small, circular, horizontal fold of dura mater, which forms a roof for the sella turcica and almost completely covers the hypophysis cerebri ; a small opening in its centre transmits the infundibulum.

Structure.—The cranial dura mater consists of white fibrous tissue and elastic fibres arranged in flattened laminæ, which are imperfectly separated by lacunar spaces and blood-vessels into the endosteal and meningeal layers, already referred to. The endosteal layer is the internal periosteum for the cranial bones, and contains the blood-vessels for their supply. At the margin of the foramen magnum it is continuous with the pericranium. The meningeal later is lined on its inner surface by a layer of nucleated mesothelium.

The *arteries* of the dura mater are very numerous. Those in the anterior fossa of the skull are the anterior meningeal branches of the anterior and posterior ethmoidal and internal carotid arteries, and a branch from the middle meningeal artery. Those in the middle fossa are the middle and accessory meningeal branches of the maxillary artery ; a branch from the ascending pharyngeal artery, which enters the skull through the foramen lacerum ; branches from the internal carotid artery, and a recurrent branch from the lacrimal artery. Those in the posterior fossa are meningeal branches from the occipital

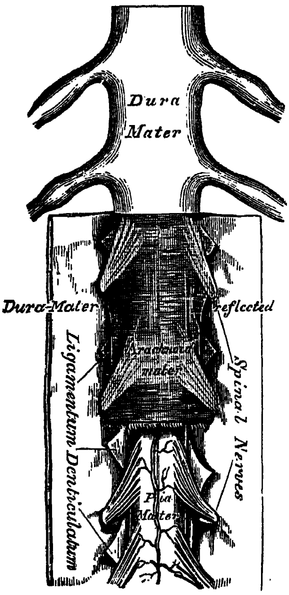
artery, one entering the skull through the jugular foramen, and another through the mastoid foramen; the posterior meningeal branches of the vertebral artery; occasional meningeal branches from the ascending pharyngeal artery, entering the skull through the jugular foramen and anterior condylar canal.

The *veins* returning the blood from the cranial dura mater anastomose with the diploic veins and end in the cranial blood-sinuses. Many of the meningeal veins do not open directly into the sinuses, but indirectly through a series of *venous lacunæ* (fig. 926). These lacunæ are found on each side of the superior sagittal sinus, especially near its middle portion, and are often invaginated by arachnoid granulations; they communicate with the diploic and emissary veins.

The *nerves* of the cerebral dura mater are filaments from the ganglion of the trigeminal nerve, from the ophthalmic, maxillary, mandibular, vagus, and hypoglossal nerves, and from the sympathetic.

The spinal dura mater (figs. 924, 927) forms a loose sheath around the spinal cord, and represents only the inner, or meningeal, layer of the cerebral dura mater; the outer, or endosteal, layer ceases at the foramen magnum, its place being taken by the periosteum lining the vertebral canal. The spinal dura mater is separated from the wall of the vertebral canal by a space, named the *extradural space*, which contains a quantity of loose areolar tissue and a plexus of veins; the situation of these veins between the spinal dura mater and the periosteum of the vertebræ corresponds to that of the cranial sinuses between the meningeal and endosteal layers of the cerebral dura mater. The spinal dura mater is attached to the circumference of the foramen magnum, and to the second and third cervical vertebræ; it is also connected by fibrous slips to the posterior longitudinal ligament of the vertebræ, especially near the lower end of the vertebral canal. The subdural cavity ends at the lower border of the second sacral vertebra; below this level the dura mater closely invests the filum terminale of the spinal cord and descends to the back of the coccyx, where it blends with the periosteum. The dura mater sends tubular prolongations on the roots of the spinal nerves and on the complete spinal nerves as they pass through the intervertebral foramina. These prolongations are short in the upper part of the vertebral column, but gradually become longer below.

Fig. 924.—A portion of the spinal cord, showing its membranes.



Structure.—The spinal dura mater resembles in structure the meningeal layer of the cerebral dura mater; it consists of white fibrous and elastic tissue arranged in bands or lamellæ which, for the most part, are parallel with one another and have a longitudinal arrangement. Its internal surface is smooth and covered by a layer of endothelium. It is sparingly supplied with blood-vessels and nerves.

The **subdural space** is a potential cavity or space between the dura mater and the arachnoid mater. It contains a minute quantity of serous fluid which moistens the smooth surfaces of the opposed membranes. It does not communicate with the subarachnoid space, but is continued for a short distance on the cranial and spinal nerves, and is in free communication with the lymph-spaces of the nerves. On the optic nerve it is continued as far as the back of the eyeball.

The Arachnoid Mater

The **arachnoid mater** is a delicate membrane enveloping the brain and spinal cord and lying between the pia mater internally and the dura mater externally. It is separated from the dura mater by the *subdural space*, but here and there this space is traversed by isolated connective tissue trabeculæ which are most numerous on the posterior surface of the spinal cord. It is separated from the pia mater by the *subarachnoid space*, which is filled with cerebrospinal fluid.

The arachnoid mater surrounds the cranial and spinal nerves, and encloses them in loose sheaths as far as their points of exit from the skull and vertebral canal.

The *cerebral part of the arachnoid mater* invests the brain loosely, and does not dip into the sulci between the gyri, nor into the fissures, with the exception of the longitudinal. On the upper surface of the brain it is thin and transparent; at the base it is thicker, and slightly opaque towards the central part, where it extends between the two temporal lobes in front of the pons, so as to leave a considerable interval between it and the pia mater. It cannot be identified in the hypophyseal fossa.

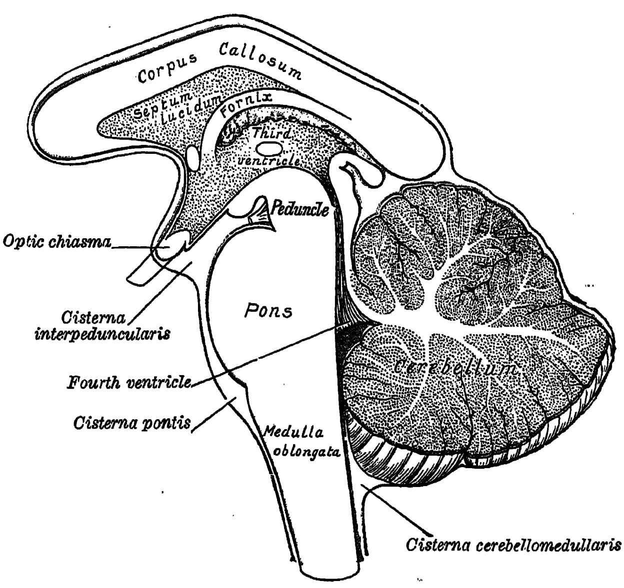
The *spinal part of the arachnoid mater* (figs. 924, 927) is a thin, delicate, tubular membrane loosely investing the spinal cord. Above, it is continuous with the cerebral arachnoid; below, it widens out, invests the cauda equina, and ends at the level of the lower border of the second sacral vertebra.

Structure.—The arachnoid mater consists of bundles of white fibrous and elastic tissue intimately blended together. Its outer surface is covered with a layer of endothelium. Vessels of considerable size, but few in number, and, according to Bochdalek, a rich plexus of nerves derived from the motor root of the trigeminal, the facial, and the accessory nerves, are found in the cerebral part of the arachnoid.

The **subarachnoid space** is the interval between the arachnoid and pia mater. It contains the cerebrospinal fluid and the larger blood-vessels of the brain, and is traversed by a network of delicate connective tissue trabeculæ, which connect the arachnoid to the pia mater. The pia and the arachnoid mater are in close contact on the summits of the cerebral gyri; but where the arachnoid bridges the sulci, angular spaces are left, in which the subarachnoid trabecular tissue is found. At certain parts of the base of the brain, the arachnoid mater is separated from the pia mater by wide intervals, which communicate freely with each other and are named *subarachnoid cisternæ*; in these the subarachnoid tissue is less abundant.

The **subarachnoid cisternæ** (fig. 925).—The *cisterna cerebellomedullaris* is triangular on sagittal section, and is formed by the arachnoid mater bridging the interval between the medulla oblongata and the under surface of the cerebellum; it is continuous below with the subarachnoid space of the spinal cord. The *cisterna pontis* is an extensive space on the ventral surface of the pons. It contains the basilar artery, and is continuous below with the subarachnoid space of the spinal cord, behind with the cerebellomedullary cisterna, and in front of the pons with the cisterna interpeduncularis. As the arachnoid mater extends across between the two temporal lobes, it is separated from the cerebral peduncles and the structures in the interpeduncular fossa by the *cisterna interpeduncularis*, which contains the circulus arteriosus. Anteriorly the interpeduncular cisterna is continued in front of the optic chiasma and is prolonged on the surface of the corpus callosum; here the arachnoid mater stretches between the cerebral

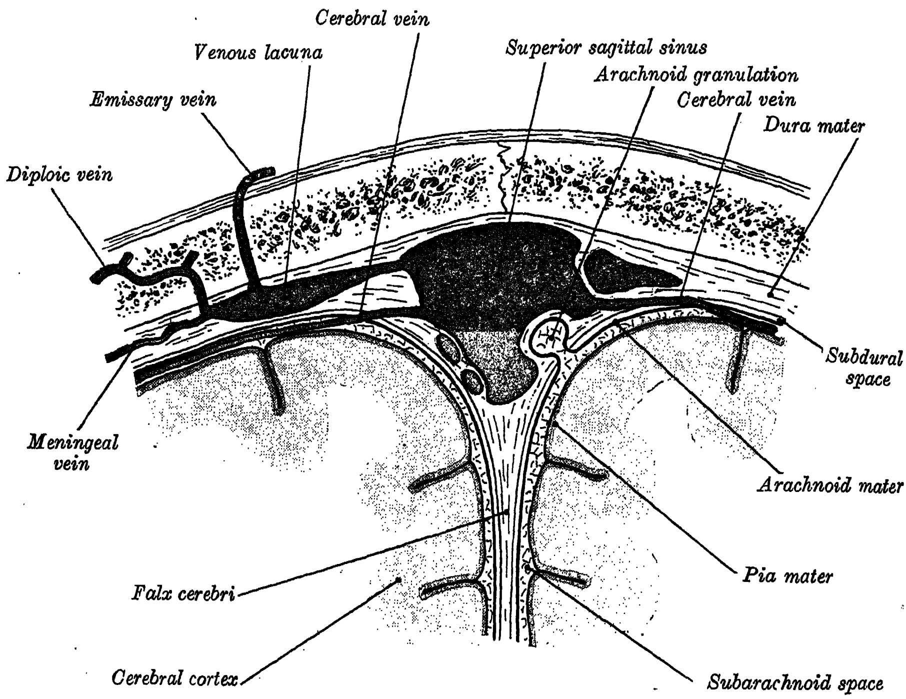
FIG. 925.—A diagram showing the positions of the three principal subarachnoid cisternæ.



hemispheres immediately below the free border of the falx cerebri, and this leaves a space in which the anterior cerebral arteries are contained. The *cisterna of the lateral sulcus* contains the middle cerebral artery, and is formed in front of each temporal lobe by the arachnoid mater bridging the lateral cerebral sulcus. The *cisterna venæ magnæ cerebri* occupies the interval between the splenium of the corpus callosum and the superior surface of the cerebellum ; it contains the great cerebral vein.

The subarachnoid space communicates with the general ventricular cavity of the brain by three openings : one, the *median aperture*, is in the median plane at the inferior part of the roof of the fourth ventricle ; the other two are at the extremities of the lateral recesses of that ventricle, behind the upper roots of the glossopharyngeal nerves (p. 940). There is no direct communication between the subdural and subarachnoid spaces. Communications exist between

FIG. 926.—A coronal section through the top of the skull, showing the membranes of the brain, etc. Diagrammatic. (Modified from Testut.)



the tissue spaces in the nasal mucous membrane and the subarachnoid space through channels which are present along the course of the olfactory nerves.

The spinal part of the subarachnoid space is a wide interval, and is largest at the lower part of the vertebral canal, where the arachnoid mater encloses the nerves which form the cauda equina. Above, it is continuous with the cranial subarachnoid space ; below, it ends at the level of the lower border of the second sacral vertebra. It is partially divided by a longitudinal septum, named the *subarachnoid septum*, which connects the arachnoid with the pia mater opposite the posterior median sulcus of the spinal cord, and forms a partition, incomplete and cribriform above, but more complete in the thoracic region. The spinal subarachnoid cavity is further subdivided by the *ligamentum denticulatum* (p. 1030).

The **arachnoid granulations** (fig. 926) are small fleshy-looking elevations, usually collected in clusters, which are present in the vicinity of the superior sagittal, transverse, and some other sinuses. When the sagittal sinus and the venous lacunæ on each side of it are opened, granulations will be found protruding into their interior. On close inspection they may be seen at the age of eighteen months, " and at the age of three they are disseminated over a considerable area " ; they increase in number and size as age advances. They are enlarged, or distended, normal villi of the arachnoid mater ; they cause

absorption of the bone, and so produce the pits or depressions on the inner aspect of the skull-cap.

Structure.—The growth and structure of the arachnoid granulations have been described by le Gros Clark.* Histologically each granulation appears as a diverticulum of the subarachnoid space, penetrating into the interstices of the dura mater, and covered by a layer of flattened cells containing large oval nuclei and lightly staining protoplasm. In the subarachnoid space there is a reticulum of fine fibrous tissue, the density of which is as a rule greater at the periphery than at the centre of the granulation; in advanced age it frequently contains calcareous nodules.

At the summit of the granulation the endothelial cells proliferate and form a cap which penetrates the surrounding dura mater, and fuses with the endothelial lining of one of the intradural venous sinuses; in doing so it pulls out a little stalk of arachnoid mater containing a diverticulum of the subarachnoid space. Except at the point of fusion with the endothelial lining of the sinus, the granulation is surrounded by the subdural space and the dura mater; the latter, covered on its cerebral surface by a layer of endothelium, is invaginated into the venous sinus by the protrusion of the granulation.

Fluid injected into the subarachnoid space passes into these granulations, and it has been found experimentally that fluid passes by osmosis from the arachnoid villi into the venous sinuses of the dura mater.

The cerebrospinal fluid is a clear, slightly alkaline fluid, with a specific gravity of about 1007. It contains in solution inorganic salts similar to those in the blood-plasma, and also traces of protein and glucose. The cerebrospinal fluid is secreted into the ventricles of the brain by the choroid plexuses and into the subarachnoid space by the choroid plexuses of the lateral recesses of the fourth ventricle (p. 940). From the ventricles it passes through the median aperture and the foramina of the lateral recesses of the fourth ventricle and so gains the subarachnoid space in the cisterna cerebellomedullaris and the cisterna pontis. Within the cranium the cerebrospinal fluid flows upwards through the gap in the tentorium cerebelli and then forwards and laterally over the inferior surface of the cerebrum. Finally it ascends over the lateral aspect of each hemisphere to reach the arachnoid villi associated with the superior sagittal sinus, and so is able to pass back again into the bloodstream. Within the vertebral canal there is no active flow, but the process of diffusion and alterations of posture serve to maintain the character of the fluid constant throughout the whole extent of the subarachnoid space. The cerebrospinal fluid supports and protects the delicate structure of the brain and spinal cord, and it maintains a uniform pressure upon them. In addition, since the perforating branches of the cerebral arteries are accompanied by perivascular channels which communicate with the subarachnoid space, on the one hand, and perineuronal spaces on the other, the cerebrospinal fluid comes into intimate relation with the nerve-cells of the cortex and basal nuclei. Our knowledge of the circulation of the cerebrospinal fluid and of the arachnoid villi has been greatly extended by the work of Weed and his collaborators.†

Applied Anatomy.—Diseases of the central nervous system and its membranes are often reflected in alterations of the cells which are normally found in the cerebrospinal fluid or in alterations in the concentration of its chemical constituents. Interference with the circulation of the fluid is indicated by variations in the pressure within the meninges. The determination of these alterations and variations is often of service in diagnosis.

Specimens of the cerebrospinal fluid may be obtained by the operation of *lumbar puncture*, which is performed through the interval between the laminæ or spines of the third and fourth (or fourth and fifth) lumbar vertebræ. A fine trocar and cannula is inserted at the point of intersection of the intertubercular plane with the posterior median line and is passed obliquely upwards and forwards above the upper border of the spine of the fourth lumbar vertebra. It is carried through, or parallel to, the supraspinous and interspinous ligaments into the vertebral canal. The dura mater and the arachnoid are punctured and the instrument is introduced into the subarachnoid space below the lower end of the spinal cord (p. 887). When the trocar is withdrawn, the cerebrospinal fluid escapes through the cannula at the rate of one drop per second, under normal conditions, but when the fluid is under increased pressure it escapes in an almost continuous stream. If it is suspected that the cerebrospinal fluid is under increased pressure at the time of a lumbar puncture, a manometer is attached to the cannula, lest the sudden fall in pressure, which would otherwise occur, should lead to impaction of the medulla oblongata in the foramen magnum, causing sudden death.

The Pia Mater

The pia mater closely invests the brain and spinal cord; it is a vascular membrane, consisting of a minute plexus of blood-vessels held together by an

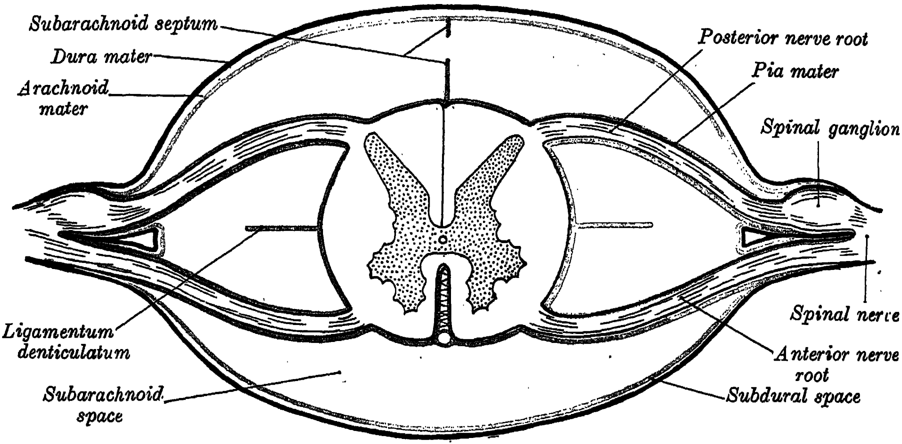
* W. E. le Gros Clark, *Journal of Anatomy*, vol. lv. 1920.

† Lewis H. Weed, Carnegie Institute of Washington; *Contributions to Embryology*, vol. 9, 1920.

extremely fine areolar tissue. The *cerebral pia mater* invests the entire surface of the brain, dips between the cerebral gyri and between the cerebellar laminæ, and is invaginated to form the tela chorioidea of the third ventricle, and the choroid plexuses of the lateral and third ventricles (pp.1014 to 1016); as it passes over the roof of the fourth ventricle, it forms the tela chorioidea and the choroid plexuses of this ventricle (p. 940). Upon the surfaces of the hemispheres it gives off from its deep surface a multitude of sheaths around the minute vessels that run perpendicularly for some distance into the cerebral substance. On the cerebellum the membrane is more delicate ; the vessels from its deep surface are shorter, and its relations to the cortex are not so intimate. Like the arachnoid mater, the pia mater cannot be identified in the hypophyseal fossa.

The *spinal pia mater* (figs. 924, 927) is thicker, firmer, and less vascular than the cerebral pia mater ; this is due to the fact that it consists of two layers, the outer or additional one being composed of bundles of connective tissue fibres, arranged for the most part longitudinally. Between the layers are cleft-like spaces which communicate with the subarachnoid space, and a

FIG. 927.—A transverse section through the spinal cord and its membranes. Diagrammatic.



number of blood-vessels. The spinal pia mater covers the spinal cord, and is intimately adherent to it ; in front it sends a septum into the anterior median fissure. A longitudinal fibrous band, called the *linea splendens*, extends along the median plane anteriorly, and a somewhat similar band, named the *ligamentum denticulatum*, is situated on each side. Below the conus medullaris the pia mater is continued as a long slender filament, named the *filum terminale* (p. 876).

The pia mater forms sheaths for the cranial and spinal nerves ; these sheaths are closely connected with the nerves, and blend with their common membranous investments.

The **ligamentum denticulatum** (figs. 839, 927) is a narrow, fibrous band situated on each side of the spinal cord, between the anterior and the posterior nerve-roots. Its medial border is continuous with the pia mater at the side of the spinal cord. Its lateral border presents a series of triangular tooth-like processes, the points of which are fixed at intervals to the dura mater. These processes are twenty-one in number, on each side. The first process crosses behind the vertebral artery at the point where that vessel pierces the dura mater, and is separated by the artery from the anterior root of the first cervical nerve ; it is attached to the dura mater immediately above the margin of the foramen magnum, 1·26 cm. behind the hypoglossal nerve, and the spinal part of the accessory nerve ascends on its posterior aspect. The last process is between the exits of the twelfth thoracic and first lumbar nerves, and consists of a narrow oblique band running downwards and laterally from the conus medullaris (Parsons *).

* *Proceedings of the Anatomical Society of Great Britain and Ireland*, 1915.

THE PERIPHERAL PART OF THE NERVOUS SYSTEM

The peripheral nervous system comprises the afferent, or centripetal, fibres which connect the sensory end-organs to the central nervous system, and the efferent, or centrifugal, fibres which connect the central nervous system to the effector apparatus. It includes the twelve pairs of cranial nerves which arise from the brain, and the thirty-one pairs of spinal nerves which arise from the spinal cord. The sympathetic trunks with their various ganglia and branches belong to this system, but they will be dealt with in a separate section.

In the lowest vertebrates the spinal cord gives rise to a series of ventral nerve-roots, arising from the anterior grey column and motor in function, and a series of dorsal nerve-roots, connected to the posterior grey column and sensory in function. The ventral and dorsal nerve-roots do not unite, and they do not correspond in position. The ventral nerve-root is segmental and is distributed to the myotome which corresponds to the neuromere from which it arises. The dorsal nerve-root is intersegmental in position and runs in the intersegmental connective tissue to reach its cutaneous distribution. In the majority of fishes and in all higher forms the corresponding ventral and dorsal nerve-roots which emerge from the spinal cord unite with one another to constitute the individual spinal nerves. The arrangement of the spinal nerves, therefore, follows a very primitive pattern and has not undergone much modification in the process of evolution.

The arrangement of the cranial nerves, on the other hand, has been very profoundly modified. The development and modification of the branchial system and the suppression of segments owing to the elaborate changes which occur in the region of the head have been largely responsible for this modification. There is every reason to suppose that the brain, like the spinal cord, represents a number of neuromeres, and that in the ancestral form of vertebrates each neuromere was provided with a ventral nerve and each interneuromeric interval with a dorsal nerve. In the brain, corresponding ventral and dorsal nerves never fuse, although adjoining ventral or dorsal nerves may and actually do unite. Owing to the complete disappearance of certain myotomes the corresponding ventral nerves become completely suppressed. Further, the dorsal nerves, originally sensory nerves supplying chiefly the skin of the head and the mucous membrane of the mouth and pharynx, acquire motor fibres which they distribute to the musculature arising in the lateral mesodermic plates in the branchial region. With the growth and modification of the brain and the consequent elaboration of the head region, the cutaneous areas of the head are transferred from one nerve to its neighbour, so that the functions of the individual dorsal nerves become altered.

The incorporation of some of the precervical segments in the head leads to the fusion of the corresponding ventral nerves, and the hypoglossal nerve so formed becomes added to the cranial nerves.

As a result of these changes the reference of the individual cranial nerves to their appropriate neuromeres and somites becomes a matter of great difficulty and complexity, and in the account which follows the nerves will be described in their numerical order.

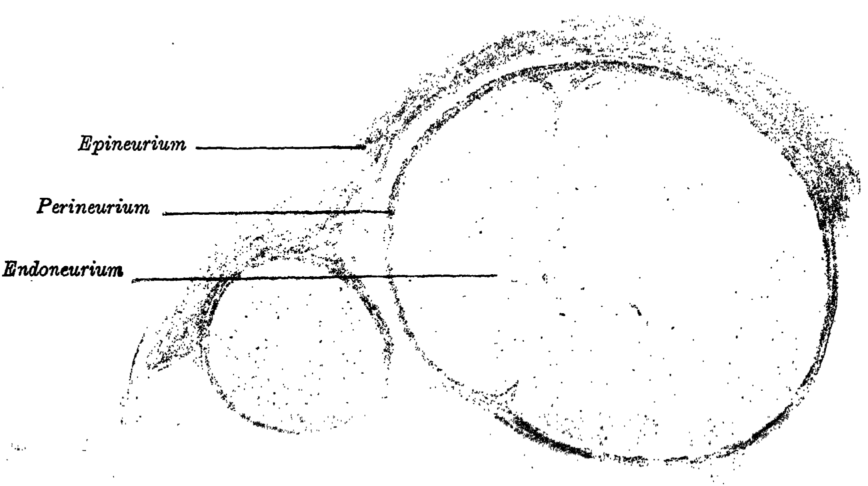
The Structure of the Peripheral Nerves and Ganglia

The **cerebrospinal nerves** consist of numerous nerve-fibres collected into bundles, which are enclosed in membranous sheaths (fig. 928) ; a small bundle of fibres is called a *funiculus*. Each funiculus is surrounded by a sheath, named the *perineurium* ; this consists of a fine, smooth, transparent membrane, made up of connective tissue which has a lamellar arrangement ; the sheath may be easily separated, in the form of a tube, from the fibres it encloses. The nerve-fibres are held together and supported within the funiculus by delicate connective tissue called the *endoneurium* ; it is continuous with septa which pass inwards from the perineurium, and shows a ground substance in which are imbedded fine bundles of fibrous connective tissue running for the most part

longitudinally. If the nerve is small, it may consist of only a single funiculus; but if large, it consists of several funiculi held together and invested by connective tissue; this investment is known as the *epineurium*. The cerebrospinal nerves consist almost exclusively of medullated nerve-fibres, only a very small proportion of non-medullated fibres being present.

The blood-vessels supplying a nerve end in a minute plexus of capillaries which pierce the perineurium, and run, for the most part, parallel with the fibres; they are connected together by short, transverse vessels, forming narrow, oblong meshes, similar to the capillary system of muscle. Fine, non-medullated, vasomotor nerve-fibres accompany these vessels, and break up into fine fibrils which form a network around them. Medullated fibres, termed *nervi nervorum*, run in the epineurium and terminate in oval or bulbous corpuscles (p. 1216).

Fig. 928.—A transverse section through two funiculi of a human nerve. Stained with hæmatoxylin. × 30.



The cerebrospinal nerve-fibres pursue an uninterrupted course from the centre to the periphery, but in separating a nerve into its component funiculi, it may be seen that bundles of fibres from one funiculus occasionally join, at a very acute angle, another funiculus proceeding in the same direction.

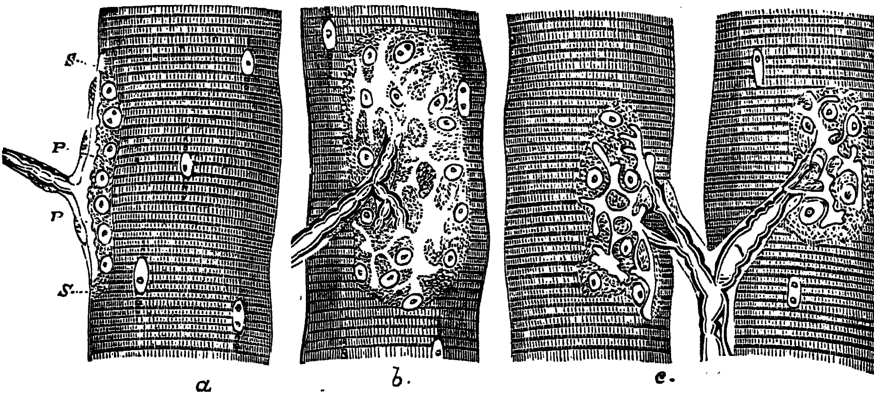
In their course, nerves subdivide into branches, and these frequently communicate with branches of neighbouring nerves; such communications form what is called a *nerve-plexus*. Sometimes a plexus is formed by the primary branches of the trunks of the nerves—as, for example, the cervical, brachial, lumbar, and sacral plexuses—and occasionally by the terminal funiculi, as in the plexuses formed at the periphery of the body. In the formation of a plexus, the component nerves divide, then join, and again subdivide in such a complex manner that the individual funiculi become intricately interlaced; so that each branch leaving a plexus may contain filaments from all the primary nerve-trunks entering the plexus. In the formation also of smaller plexuses at the periphery of the body there is a free interchange of funiculi and fibres. In each case, however, the individual fibres remain separate and distinct.

Through this interchange of fibres, every nerve leaving a plexus gains a more extensive connexion with the spinal cord than if it had proceeded direct to its distribution without joining other nerves. Consequently the parts supplied by these nerves have more extended relations with the nervous centres; by this means also, groups of muscles may be associated for combined action.

Origins of nerves.—The origin of a nerve is in some cases single—that is to say, the whole nerve emerges from the nervous centre by a single root; in other instances the nerve arises by two or more roots. The point where the nerve-root

or roots emerge from the surface of the nervous centre is named the *superficial*, or *apparent*, origin, but the fibres of the nerve can be traced to groups of nerve-cells in the grey matter of the nervous centre; these cell-groups constitute the *deep*, or *real*, origin of the nerve. The centrifugal, or efferent, nerve-fibres

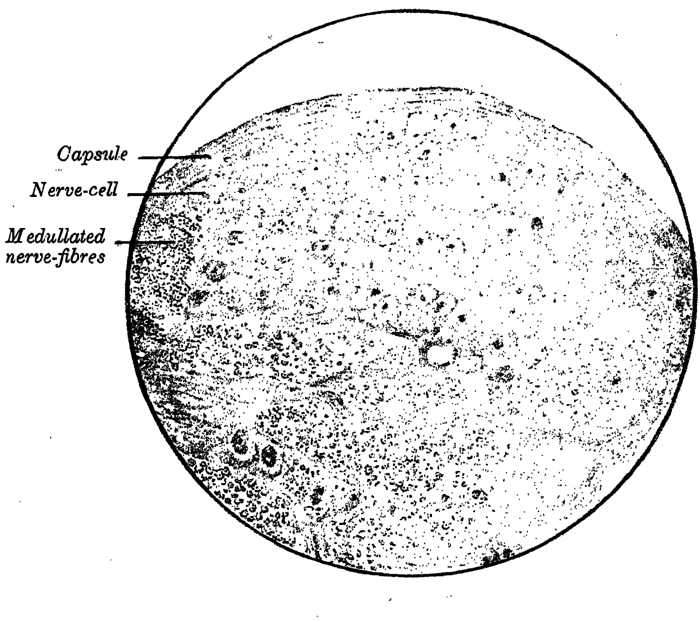
FIG. 929.—Muscular fibres of *Lacerta viridis* with the terminations of nerves.



a. Seen in profile. P.P. The motor end-plate. S.S. The base of the plate, consisting of a granular mass with nuclei. *b*. The same as seen in looking at a perfectly fresh fibre, the nerve-ends being probably still excitable. *c*. The same as seen two hours after death from poisoning by curare.

are the axons of nerve-cells situated in the grey matter of the central nervous system. The centripetal, or afferent, nerve-fibres spring from nerve-cells in the organs of special sense (e.g. the retina) or from nerve-cells in the ganglia. Having entered the nerve-centre they branch and send their ultimate twigs among its cells, without, however, uniting with them.

FIG. 930.—A transverse section through a human spinal ganglion. Stained with methylene blue. Note the brown pigment in some of the ganglion cells. × 60.

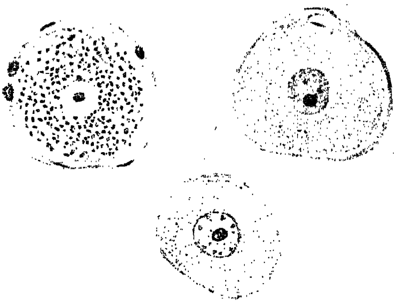


Peripheral terminations of nerves.—Nerve-fibres terminate peripherally in various ways. The terminations of the sensory nerves are dealt with on pp. 1216-1219.

Motor nerves ending in *striped*, or *voluntary*, *muscle* enter the sheath of the muscle, break up into fibres, or bundles of fibres, which form plexuses, and

gradually divide until, as a rule, a single nerve-fibre enters a single muscular fibre; if the muscular fibre is long, more than one nerve-fibre may enter it. Within the muscular fibre the nerve ends in a special expansion, called by Kühne, who first described it accurately, a *motor end-plate* (fig. 929). The nerve-fibre, on approaching the muscular fibre, suddenly loses its medullary sheath, the neurolemma becomes continuous with the sarcolemma of the muscle, and only the axis-cylinder with a thin covering of protoplasm enters the muscular fibre. There it ramifies immediately beneath the sarcolemma, and becomes imbedded in a layer of granular matter, containing a number of clear, oblong nuclei, the whole constituting a motor end-plate, from which the contractile wave of the muscular fibre is said to start (see also p. 34). It should be noted that, whereas the motor nerve-endings in muscle are situated under the sarcolemma, the sensory nerve-endings lie outside that layer.

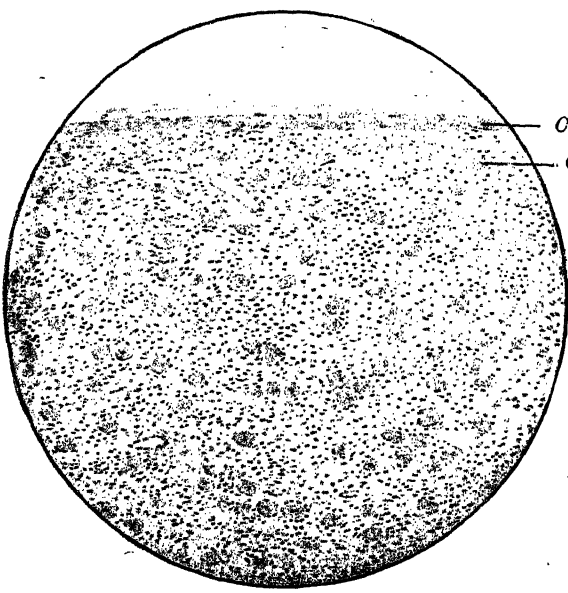
Fig. 931.—Three types of nerve-cells from a spinal ganglion of a cat. Stained with hæmatoxylin and eosin. ×350. (The nuclei of the cells lining the capsule are shown in the left-hand figure only.)



Non-medullated fibres also have been traced to muscle fibres, where they end in an elongated motor plate with numerous minute terminal grape-like enlargements, which are situated on the surface of the sarcolemma. They are believed to be sympathetic in character. (Kulchitsky, *Journ. of Anat.*, Jan. 1924.)

Ganglia are small aggregations of nerve-cells. They are found on the posterior roots of the spinal nerves; on the sensory roots of the trigeminal,

Fig. 932.—A section through a human sympathetic ganglion. Stained with hæmatoxylin and eosin. ×60.



facial, glossopharyngeal, and vagus nerves and on the auditory nerves. They are also found in connexion with the sympathetic nerves. They consist of a reddish-grey substance, traversed by numerous white nerve-fibres, and vary considerably in form and size. Each ganglion is invested by a smooth, firm, membranous envelope, consisting of dense areolar tissue; this envelope is

continuous with the perineurium of the nerves, and sends numerous processes into the interior of the ganglion.

Ganglia consist of nerve-cells and nerve-fibres. Each nerve-cell has a nucleated capsule which is continuous with the neurolemma of the nerve-fibre connected with the cell. The typical larger nerve-cells in the ganglia of the spinal nerves (figs. 930, 931) are irregularly spherical in shape, and each gives off a single fibre which runs towards the centre of the ganglion, and divides in a T-shaped manner; one limb of the cross-bar enters the spinal cord, the other passes outwards to the periphery. Near its origin the stem of the axon is coiled on itself, forming a *glomerulus*. As it straightens out it acquires a medullary sheath, and it usually divides at its first node of Ranvier. The typical smaller cells, which are very numerous, give off fine unmedullated fibres. These axons do not form such complicated glomeruli and they may be practically straight. The presence of plexuses of finely medullated or unmedullated fibres around the cell-bodies has been described by Dogiel, who regards them as being sympathetic in origin. The same authority has described several additional varieties of cells in the spinal ganglia. In one type, the peripheral division of the axon breaks up within the ganglion into sensory nerve-endings; in another, the cell is multipolar and, while the medullated axon passes centrally into the spinal cord, the dendrites, which are peculiar in that they may be partly medullated, break up into sensory endings within the ganglion.

Structurally the peripheral division of the axon of an unipolar ganglion cell resembles an axon in every respect, but it functions as a greatly elongated dendrite.

THE CRANIAL NERVES

There are twelve pairs of cranial (cerebral) nerves, which are named from before backwards as follows:

1st. Olfactory.	5th. Trigeminal.	9th. Glossopharyngeal.
2nd. Optic.	6th. Abducent.	10th. Vagus.
3rd. Oculomotor.	7th. Facial.	11th. Accessory.
4th. Trochlear.	8th. Auditory.	12th. Hypoglossal.

These nerves are attached to the brain, and are transmitted through openings in the base of the cranium. The **motor**, or efferent, cranial nerves arise within the brain from groups of nerve-cells which constitute their *nuclei of origin*. They are brought into relationship with the cerebral cortex by the geniculate fibres of the internal capsule; these fibres arise from the cells of the motor area of the cortex, cross the median plane and end by arborising round the cells of the nuclei of origin of the motor cranial nerves. The **sensory**, or afferent, cranial nerves arise from nerve-cells outside the brain; these nerve-cells may be grouped to form ganglia on the trunks of the nerves, or may be situated in peripheral sensory organs such as the nose, eye and ear. The centrally directed processes of the cells run into the brain and there end by arborising around nerve-cells which are grouped to form the *nuclei of termination* of the ordinary sensory nerves. Fibres arise from the cells of these nuclei and, after crossing to the opposite side, join the lemnisci, and thus connect the nuclei indirectly with the cerebral cortex.

The fibres of most of the cranial nerves begin to acquire their myelin sheaths about the fourteenth week of intra-uterine life. The process is delayed until the twenty-second week in the cases of the sensory part of the trigeminal nerve and the cochlear division of the auditory nerve. In the case of the optic nerve myelination does not commence until shortly before birth, and it is not completed until the second week after birth.*

The Olfactory Nerves (fig. 933)

The **olfactory nerves**, or nerves of smell, are distributed to the mucous membrane of the olfactory region of the nasal cavity; this region comprises the

* M. F. Lucas Keene and E. E. Hewer, *Journal of Anatomy*, vol. lxvi. 1931.

superior nasal concha, and the opposed part of the nasal septum. The nerve-fibres originate from the central, or deep, processes of the olfactory cells of the nasal mucous membrane, and are collected into bundles which cross one

FIG. 933.—The nerves of the septum of the nose. Right side.

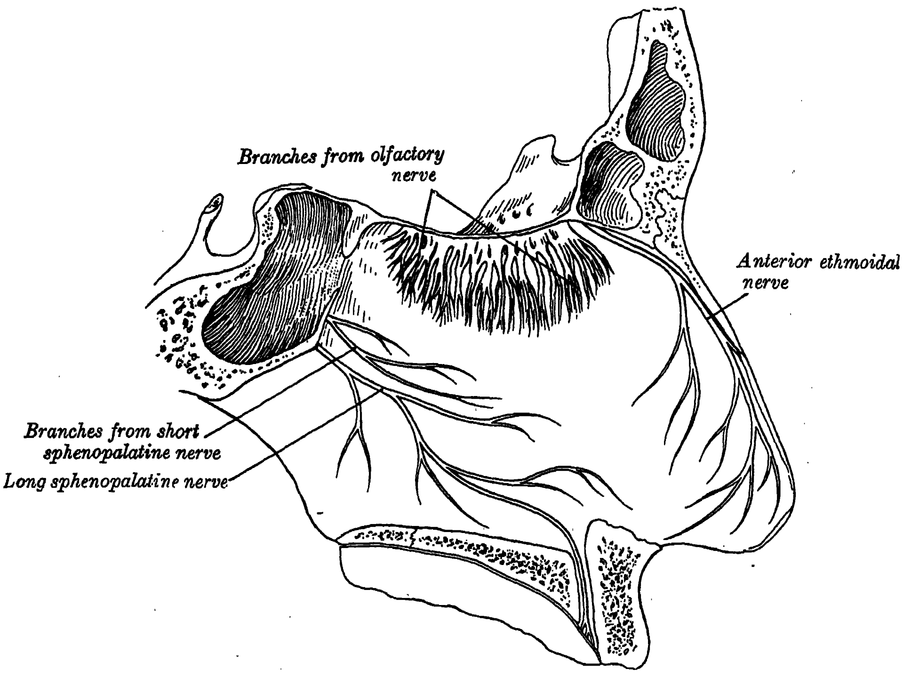
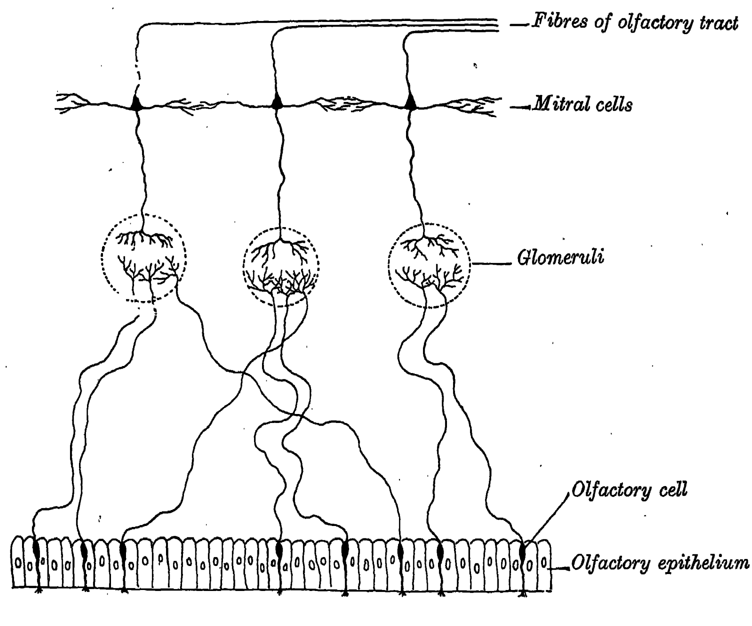


FIG. 934.—A plan of the olfactory neurons.



another in various directions, and thus give rise to the appearance of a plexiform network in the mucous membrane. They are then collected into about twenty branches, which pierce the cribriform plate of the ethmoid bone in lateral and medial groups, and end in the glomeruli of the olfactory bulb (fig. 934). Each branch receives tubular sheaths from the dura mater and pia-arachnoid,

the former being continued into the periosteum of the nose, the latter into the neurolemma of the nerve.

The olfactory nerves are non-medullated, and consist of axis-cylinders surrounded by nucleated sheaths, in which, however, there are fewer nuclei than in the sheaths of ordinary non-medullated nerve-fibres.

The olfactory nerves are unique in that their cells of origin develop in the ectoderm and retain this position throughout life in all forms.

Closely associated with the olfactory nerves is a pair of small nerves named the *nervi terminales*.

These nerves were first seen in the lower vertebrates, but their presence has been demonstrated in the human embryo and adult. They consist chiefly of non-medullated nerve-fibres, and on them there are small groups of bipolar and multipolar nerve-cells. Each nerve runs along the medial side of the corresponding olfactory tract, and its branches traverse the cribriform plate of the ethmoid bone, and are distributed to the nasal mucous membrane. Centrally the nerve is connected to the brain at the olfactory trigone; in some animals its fibres have been traced to the lamina terminalis: in others to the hypothalamic region. Its function is unknown; some are inclined to view it as a forward extension of the cephalic part of the sympathetic which is distributed to the blood-vessels and glands of the nasal cavity.

The central connexions of the olfactory bulb are described on pp. 984-988.

Applied Anatomy.—In severe injuries to the head involving the anterior cranial fossa, the olfactory bulb may become separated from the olfactory nerves, or the nerves may be torn, thus producing loss of smell (*anosmia*).

Anosmia sometimes occurs after acute infections of the nose.

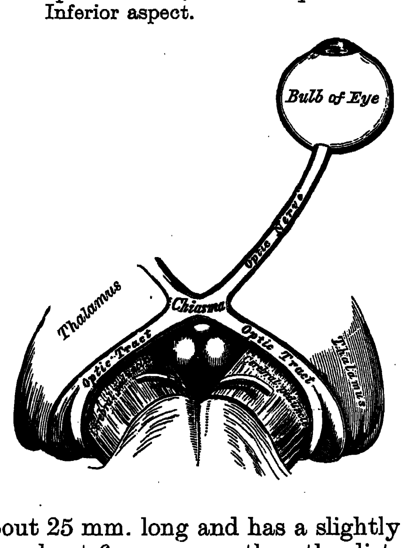
THE OPTIC NERVE (fig. 935)

The **optic nerve**, or nerve of sight, is distributed to the eyeball. Most of its fibres are afferent and originate in the nerve-cells of the ganglionic layer of the retina (p. 1174), but a few are efferent and spring from nerve-cells in the lower visual centres of the brain (p. 968). Developmentally, the optic nerves and the retinæ are parts of the brain (p. 125).

The fibres of the optic nerve form the innermost layer (stratum opticum) of the retina; they converge to the optic disc, and there pierce the outer layers of the retina, the choroid coat, and the lamina cribrosa of the sclera at the posterior part of the eyeball, about 3 or 4 mm. to the nasal side of its centre. As the nerve-fibres traverse the lamina cribrosa they receive their medullary sheaths, and run in bundles which are collected to form the optic nerve.

The optic nerve, about 4 cm. long, is directed backwards and medially through the posterior part of the orbital cavity. It then runs through the optic foramen into the cranial cavity and joins the optic chiasma.

FIG. 935.—The left optic nerve, the optic chiasma, and the optic tract. Inferior aspect.

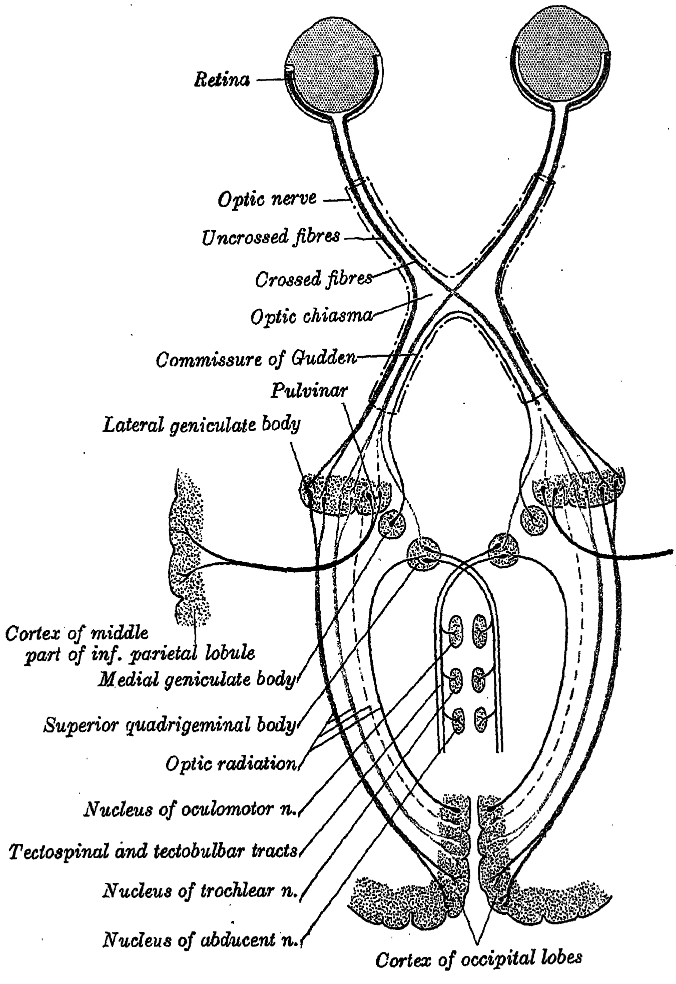


The intra-orbital part of the nerve is about 25 mm. long and has a slightly sinuous course, the length of the nerve being about 6 mm. more than the distance between the optic foramen and the eyeball. Posteriorly it is closely surrounded by the recti muscles, but anteriorly is separated from them by a quantity of fat, in which the ciliary vessels and nerves are lodged. The ciliary ganglion lies between the nerve and the rectus lateralis muscle. The inferomedial surface of the nerve is pierced, at a distance of about 12 mm. behind the eyeball, by the central artery and vein of the retina, which are then directed forwards in the centre of the nerve to the optic disc. In the optic foramen

the nerve lies above and medial to the ophthalmic artery, and is separated medially from the sphenoidal and posterior ethmoidal sinuses by a thin lamina of bone; in front of the foramen the nasociliary nerve and the ophthalmic artery run forwards and medially, crossing above the nerve.

The intracranial part of the optic nerve, about 10 mm. long, runs backwards and medially from the optic foramen to the optic chiasma. The posterior parts

FIG. 936.—A scheme showing the connexions of the optic nerves and optic tracts.



The interrupted lines indicate connexions, the existence of which is uncertain.

N.B.—*The dividing line between the decussating and the non-decussating fibres of the optic nerve passes vertically through the centre of the macula.*

of the olfactory tract and gyrus rectus, and, near the chiasma, the anterior cerebral artery lie above it. The internal carotid artery is on its lateral side.

The optic nerve consists mainly of fine medullated fibres, and is enclosed in three sheaths which are continuous with the membranes of the brain, and are prolonged as far as the back of the eyeball. The *outer sheath*, derived from the dura mater, is thick and fibrous, and blends anteriorly with the sclera. The *intermediate sheath*, derived from the arachnoid mater, is thin and delicate. It is separated from the outer sheath by the subdural space, and from the inner sheath by the subarachnoid space. The *inner sheath*, derived from the pia mater, is vascular and closely invests the nerve. From its deep surface septa pass into the nerve and subdivide and reunite to enclose what appear, in

transverse sections of the nerve, as polygonal areas, which are occupied by the bundles of nerve-fibres. From the inner sheath also, an investment is carried on the central vessels of the retina as far as the optic disc.

Close to the eyeball the macular fibres occupy the lateral part of the nerve, but, as they are traced backwards, they gradually come to lie centrally.

The **optic chiasma** (p. 967), formed by the union of the two optic nerves, is somewhat quadrilateral in shape; it lies above the tuberculum sellæ and the anterior part of the diaphragma sellæ, some distance behind the optic groove of the sphenoid bone. It forms the anterior part of the floor of the third ventricle and is in relation: above with the lamina terminalis: below with the anterior part of the interpeduncular cisterna, which separates it from the anterior part of the diaphragma sellæ: in front with the anterior cerebral and anterior communicating arteries: behind with the tuber cinereum: and laterally with the anterior perforated substance and the internal carotid artery.

The fibres of the optic nerves undergo a partial decussation in the optic chiasma (fig. 936). The fibres from the medial (nasal) half of each retina, including the medial half of the macula, cross the median plane in the anterior part of the chiasma and enter the optic tract of the opposite side. The fibres from the lateral (temporal) half of each retina, including the lateral half of the macula, do not cross, but are continued backwards, through the lateral part of the chiasma, into the optic tract of the same side. The posterior part of the chiasma consists of fibres which cross the median plane, but do not form parts of the optic nerves; these fibres connect the medial geniculate body of one side with the medial geniculate body and, possibly, the inferior quadrigeminal body of the opposite side, and constitute what is known as the *commissure of Gudden*.

The **optic tract** (fig. 876) is a cylindrical bundle of nerve-fibres which runs backwards and laterally from the optic chiasma. It passes between the anterior perforated substance and the tuber cinereum and reaches the under surface of the cerebral peduncle, where it becomes flattened. It then winds round and adheres to the cerebral peduncle, and divides into a medial and a lateral root. The fibres of the medial root form the commissure of Gudden, already referred to; the lateral, and larger, root ends in the lateral geniculate body and the superior quadrigeminal body, which together with the pulvinar of the thalamus constitute the *lower visual centres* (p. 960). From the cells of the lateral geniculate body fibres, termed the *optic radiation*, take origin, and pass through the retrolentiform part of the internal capsule to the *higher*, or *cortical*, *visual centre*, which is situated in the cuneus and in the neighbourhood of the postcalcarine and calcarine sulci. These connexions are dealt with fully on pp. 993 and 1010.

Applied Anatomy.—The optic nerve is peculiarly liable to become the seat of neuritis or undergo atrophy in affections of the central nervous system, and as a rule the pathological relationship between the two affections is exceedingly difficult to trace. There are, however, certain points in connexion with the anatomy of this nerve which tend to throw light upon the frequent association of its affections with intracranial disease. (1) From its mode of development, and from its structure, the optic nerve must be regarded as a prolongation of the brain-substance, rather than as an ordinary cranial nerve. (2) It receives sheaths from the three cerebral membranes, and these sheaths are separated from each other by spaces which communicate with the subdural and subarachnoid spaces respectively. The innermost sheath sends a process around the arteria centralis retinæ into the interior of the nerve, and enters intimately into its structure. Thus inflammatory affections of the meninges or of the brain may readily extend along these spaces, or along the interstitial connective tissue in the nerve.

The optic neuritis or papillœdema (' choked disc ') that is often seen in cases of intracranial new growth with increased intracranial tension is probably caused by increased pressure in the sheath of the optic nerve, due to excess of fluid in the general subarchnoid space with which this sheath is in direct communication. If, as is the case, for example in the internal hydrocephalus seen as a complication of cerebrospinal fever, there is no increase in the amount of fluid in the subarachnoid space, then there will be no optic neuritis although the intracranial tension may rise until it brings about the patient's death.

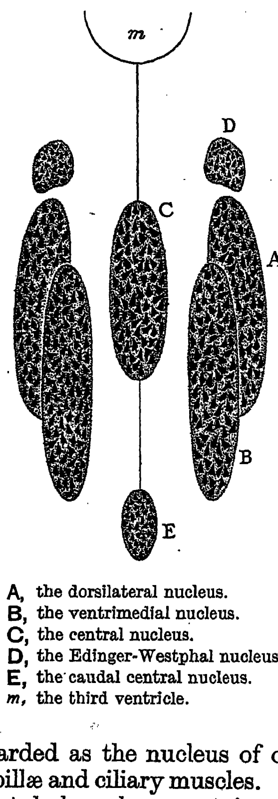
The course of the fibres in the optic chiasma has an important pathological bearing. An anteroposterior section through the chiasma would divide the decussating fibres, and would therefore produce blindness of the medial half of each eye; while a section at the margin of the side of the optic chiasma would produce blindness of the lateral half of the retina of the same side. An early symptom of tumour-growth in the hypophysis is pressure on the chiasma.

THE OCULOMOTOR NERVE (figs. 937 to 939)

The **oculomotor nerve** supplies all the ocular muscles, except the obliquus superior and rectus lateralis; it also supplies, through its connexion with the ciliary ganglion, the sphincter pupillæ and the ciliaris muscles.

The fibres of the oculomotor nerve arise from a **nucleus** which lies in the grey matter of the upper part of the floor of the aqueduct of the mid-brain and extends in front of the aqueduct for a short distance into the floor of the third ventricle, occupying the position of the somatic efferent column (p. 112). From this nucleus the fibres pass forwards through the tegmentum, the red nucleus and the medial part of the substantia nigra, forming a series of curves with a lateral convexity, and emerge from the sulcus on the medial side of the cerebral peduncle (fig. 866).

FIG. 937.—A scheme of the various groups of cells which together constitute the nucleus of the oculomotor nerve. (After le Gros Clark.)



A, the dorsilateral nucleus.
B, the ventrimedial nucleus.
C, the central nucleus.
D, the Edinger-Westphal nucleus.
E, the caudal central nucleus.
m, the third ventricle.

The nucleus of the oculomotor nerve does not consist of a continuous column of cells, but is broken up into a number of smaller nuclei: (1) the dorsilateral nucleus; (2) the ventrimedial nucleus; (3) the central nucleus; (4) the Edinger-Westphal nucleus; (5) the caudal central nucleus. The dorsilateral nucleus extends further in a headward direction than the ventrimedial nucleus, but does not extend so far caudally. The central nucleus is continuous across the median plane with the corresponding nucleus of the opposite side. These three nuclei all contain large multipolar nerve-cells, and it is believed that they supply all the striped muscle innervated by the oculomotor nerve. The evidence at present available is not conclusive, but it suggests that the dorsilateral nucleus is concerned with upward movements (superior rectus and inferior oblique muscles), the ventrimedial nucleus, which is in direct line with the nucleus of the trochlear nerve, with downward movements (inferior rectus) and the central nucleus with movements of convergence (medial rectus). The Edinger-Westphal nucleus is placed more dorsally in the central grey matter of the mid-brain and extends further in a headward direction than the other nuclei. It is generally regarded as the nucleus of origin of the fibres which innervate the sphincter pupillæ and ciliary muscles. The caudal central nucleus, which like the Edinger-Westphal nucleus contains small, stellate nerve-cells, lies in line with it and is probably similar in function.*

The whole nucleus is intimately related to the medial longitudinal bundle, which lies on its ventrilateral aspect.

Connexions.—The oculomotor nucleus receives fibres from: (1) the pyramidal tract of the opposite side; (2) the medial longitudinal bundle, by which it is connected to the nuclei of fourth, sixth and eighth cranial nerves (p. 949); and (3) the tectobulbar tract, by which it is connected to the visual cortex through the medium of the superior quadrigeminal body.

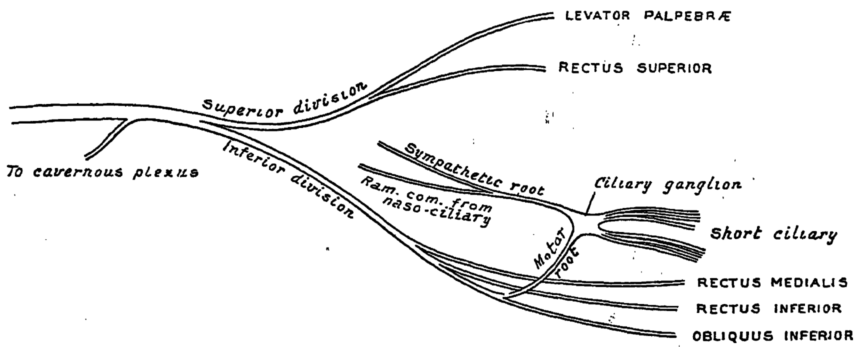
On emerging from the brain, the nerve is invested with a sheath of pia mater, and lies in the subarachnoid space. It passes between the superior cerebellar and posterior cerebral arteries, and runs forward in the interpeduncular cisterna on the lateral side of the posterior communicating artery. It

* See an article by W. E. le Gros Clark on "The Mammalian Oculomotor Nucleus," *Journal of Anatomy*, vol. lx. 1926

then perforates the arachnoid mater and lies in the triangular interval between the free and attached borders of the tentorium cerebelli. Piercing the inner layer of the dura mater on the lateral side of the posterior clinoid process the nerve traverses the lateral wall of the cavernous sinus, where it lies above the trochlear nerve. In this situation it receives one or two filaments from the internal carotid (cavernous) plexus of the sympathetic, and communicates with the ophthalmic division of the trigeminal. It then divides into a superior and an inferior ramus, which enter the orbit through the superior orbital fissure, within the annulus tendineus which gives origin to the recti muscles; here the nasociliary nerve is placed between the two rami.

The *superior ramus*, the smaller, ascends on the lateral side of the optic nerve, and supplies the rectus superior and levator palpebræ superioris. The *inferior ramus* divides into three branches (fig. 938). One passes below the

FIG. 938.—A plan of the oculomotor nerve.



optic nerve to the rectus medialis; another goes to the rectus inferior; the third and longest runs forwards between the rectus inferior and rectus lateralis, to the obliquus inferior. From the nerve to the obliquus inferior a short thick branch is given to the lower part of the ciliary ganglion, and forms its *short* or *parasympathetic root* (p. 1046). The branches enter the muscles on their ocular surfaces, with the exception of that to the obliquus inferior, which enters the posterior border of the muscle.

Applied Anatomy.—Paralysis of the oculomotor nerve leads, when complete, to (1) ptosis, or drooping of the upper eyelid, in consequence of the levator palpebræ superioris being paralysed; (2) external strabismus, on account of the unopposed action of the rectus lateralis and obliquus superior, which are not supplied by the oculomotor nerve and are therefore not paralysed; (3) dilatation of the pupil, because the sphincter pupillæ is paralysed; (4) loss of power of accommodation and of contraction on exposure to light, as the sphincter pupillæ and the ciliaris are paralysed; (5) slight prominence of the eyeball, owing to most of its muscles being relaxed; and (6) diplopia, or double vision, the false image being higher than the true. Occasionally paralysis may affect only a part of the nerve—for example, there may be a dilated and fixed pupil, with ptosis, but no other signs. Irritation of the nerve causes spasm of one or other of the muscles supplied by it; thus, there may be internal strabismus from spasm of the rectus medialis; accommodation for near objects only, from spasm of the ciliaris; or miosis (contraction of the pupil) from irritation of the sphincter pupillæ.

The oculomotor nerve is particularly liable to become involved in a syphilitic peri-arteritis, as it passes between the posterior cerebral and superior cerebellar arteries at the base of the brain.

THE TROCHLEAR NERVE (fig. 939)

The **trochlear nerve**, the slenderest of the cranial nerves, supplies the superior oblique muscle of the eyeball.

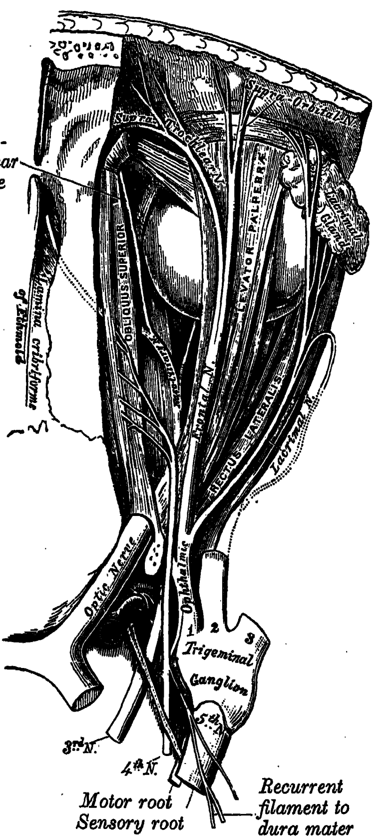
It arises from a **nucleus** situated in the floor of the aqueduct of the mid-brain, opposite the upper part of the inferior quadrigeminal body. This nucleus lies in line with the ventrimedial part of the oculomotor nucleus, and occupies the

position of the somatic efferent column. It bears an intimate relationship to the medial longitudinal bundle, which lies on its ventral aspect.

Connexions.—The nucleus of the trochlear nerve receives fibres from: (1) the pyramidal tract of the opposite side; (2) the medial longitudinal bundle, by which it is connected with the nuclei of the third, sixth and eighth cranial nerves (p. 949); and (3) with the tectobulbar tract, by which it is connected with the visual cortex through the medium of the superior quadrigeminal body (p. 952).

After leaving the nucleus the fibres of the trochlear nerve pursue a very unusual course. They first run downwards and laterally through the tegmentum and then turn backwards round the central grey matter into the upper part of the superior medullary velum. Here they decussate with the corresponding fibres of the opposite side, and, having crossed the median plane, emerge from the surface of the velum at the side of the frenulum veli, immediately behind the inferior quadrigeminal body (fig. 864).

FIG. 939.—The nerves of the right orbit. Superior aspect.



The nerve is directed across the superior cerebellar peduncle, and then winds forwards round the cerebral peduncle immediately above the pons, and between the posterior cerebral and superior cerebellar arteries. It appears between the border of the pons and the temporal lobe, and pierces the inner layer of the dura mater immediately below the free border of the tentorium cerebelli, a little behind the posterior clinoid process. It then passes forwards in the lateral wall of the cavernous sinus, below the oculomotor nerve and above the ophthalmic division of the trigeminal nerve. Near the front of the sinus it crosses the oculomotor nerve, and enters the orbit through the superior orbital fissure, above the ocular muscles, and medial to the frontal nerve. In the orbit it passes medially, above the origin of the levator palpebræ superioris, and finally enters the orbital surface of the obliquus superior.

In the lateral wall of the cavernous sinus the trochlear nerve communicates with the ophthalmic division of the trigeminal nerve, and with the internal carotid (cavernous) plexus of the sympathetic. In the superior orbital fissure it occasionally gives off a branch to the lacrimal nerve.

Applied Anatomy.—When the trochlear nerve is paralysed there is loss of function in the obliquus superior, so that the patient is unable to turn his eye downwards and laterally. Should the patient attempt to do this, the eye of the affected side is rotated medially, producing diplopia or double vision. Single vision exists in the whole of the field so long as the eyes look above the horizontal plane, diplopia occurs on looking downwards. To counteract this the patient holds his head forwards, and also inclines it to the sound side.

The Trigeminal Nerve

The **trigeminal nerve** is the largest cranial nerve. It is the sensory nerve of the face, the greater part of the scalp, the teeth, the mouth and the nasal

cavity, and the motor nerve of the muscles of mastication. It divides into three branches, viz. the ophthalmic, the maxillary, and the mandibular.

It is attached to the anterior, or ventral, surface of the pons, near its upper border, by a large sensory, and a small motor, root—the latter being placed medial and anterior to the former.

The fibres of the *sensory root* arise from the cells of the *trigeminal* (*semilunar*) *ganglion*. This ganglion (figs. 939, 940) occupies a cavity (cavum trigeminale) in the dura mater covering the trigeminal impression near the apex of the petrous part of the temporal bone (p. 1024). The ganglion is crescentic in shape, with its convexity directed forwards and laterally; its surface is obscured by a number of interlacing nerve fibres. Medially it is in relation with the internal carotid artery and the posterior part of the cavernous sinus; inferiorly, with the motor root of the nerve, the greater superficial petrosal nerve and the foramen lacerum. It receives filaments from the internal carotid plexus of the sympathetic, and gives twigs to the tentorium cerebelli.

The axis-cylinders of the cells of the trigeminal ganglion divide into peripheral and central branches. The former are grouped to form the *ophthalmic* and *maxillary* nerves, and the sensory part of the *mandibular* nerve. The central branches constitute the fibres of the sensory root of the nerve, which leaves the concave margin of the ganglion, runs backwards and medially below the superior petrosal sinus and the tentorium cerebelli, and enters the pons. In the pons these fibres divide into ascending and descending branches. The ascending branches end in the *upper sensory nucleus* of the trigeminal nerve, which is situated in the pons, lateral to, and somewhat deeper than, the motor nucleus (p. 925). It receives fibres conveying discriminative sensibility from the whole trigeminal area and probably some, if not all, of the proprioceptive fibres. The descending branches form what is named the *spinal tract* of the trigeminal nerve. This tract runs downwards through the pons into the medulla oblongata superficial to a nucleus of grey substance which is named the *nucleus of the spinal tract* of the trigeminal nerve. It is continuous inferiorly with the gelatinous substance of the spinal cord, with which it is identical in structure. As the tract descends, a succession of fibres leaves it and enters the nucleus, and the tract gradually diminishes in size, and finally ends in the upper part of the cervical portion of the spinal cord. This nucleus receives fibres conveying crude painful and thermal sensibility from the whole trigeminal area. Clinical evidence tends to show that the fibres of the ophthalmic nerve enter the lower part, those of the maxillary nerve the intermediate part, and those of the mandibular nerve the upper part of the nucleus.*

The mesencephalic nucleus of the trigeminal nerve consists of a strand of cells occupying nearly the whole length of the lateral portion of the central grey matter of the mid-brain. It was originally regarded as an additional motor nucleus, but, on the grounds of its histological characters and its developmental position in the alar lamina, J. B. Johnston has claimed it as a sensory nucleus. Kappers believes that it receives proprioceptive fibres from the muscles of mastication (p. 945). It apparently constitutes a nucleus of origin, as the fibres of the mesencephalic root of the trigeminal nerve, which runs up on its lateral side, pass through the trigeminal ganglion without interruption.

Connexions.—The new fibres which arise in these sensory nuclei cross the median plane and ascend to the lateral nucleus of the thalamus in the trigeminal lemniscus. From the thalamus they are relayed to the cortex of the postcentral gyrus.

The *motor nucleus* of the trigeminal nerve lies in the upper part of the pons, close to its dorsal surface, and along the lateral margin of the floor of the fourth ventricle. It is further from the median plane than the nuclei of the oculomotor and trochlear nerves, and it occupies the position of the branchial (special visceral) efferent column (fig. 840). It receives fibres from the pyramidal tract of the opposite side, and its outgoing fibres form the motor root.

Four small ganglia are associated with the three divisions of the trigeminal nerve, viz.—the *ciliary ganglion* with the ophthalmic nerve; the *sphenopalatine ganglion* with the maxillary nerve; and the *otic* and *submandibular* (*submaxillary*) *ganglia* with the mandibular nerve.

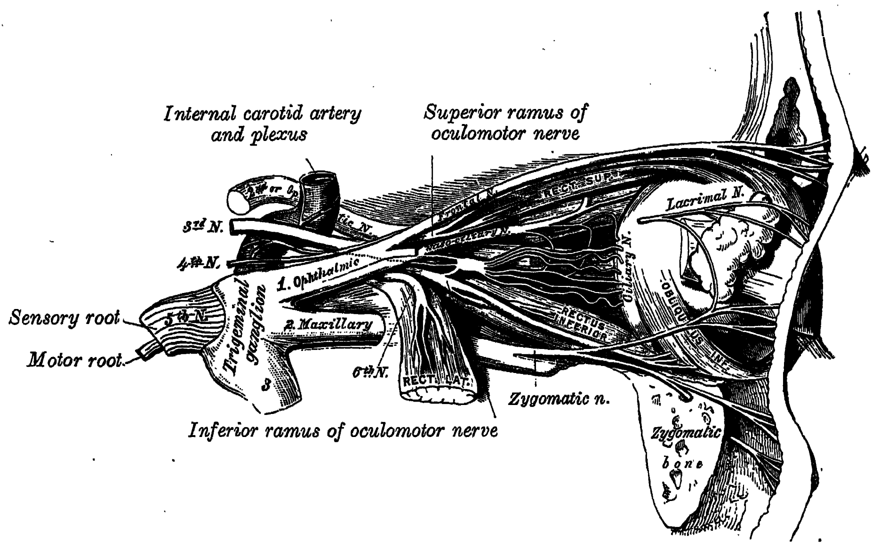
* See an article by J. S. B. Stopford, *Journal of Anatomy*, vol. lix.

The Ophthalmic Nerve (figs. 939, 940)

The **ophthalmic nerve**, the first division of the trigeminal nerve, is a sensory nerve. It supplies branches to the eyeball, the lacrimal gland and the conjunctiva, to a part of the mucous membrane of the nasal cavity, and to the skin of the nose, eyelids, forehead and scalp. It is the smallest division of the trigeminal nerve, and arises from the anteromedial part of the trigeminal ganglion as a flattened band, about 2·5 cm. long, which passes forwards along the lateral wall of the cavernous sinus below the oculomotor and trochlear nerves ; just before entering the orbit through the superior orbital fissure, it divides into three branches, viz. *lacrimal*, *frontal* and *nasociliary*.

The ophthalmic nerve is joined by filaments from the internal carotid plexus of the sympathetic, and communicates with the oculomotor, trochlear and abducent nerves ; it supplies a recurrent branch (n. tentorii), which crosses and adheres to the trochlear nerve, and is distributed to the tentorium cerebelli.

Fig. 940.—The nerves of the right orbit, and the ciliary ganglion. Lateral aspect.



The **lacrimal nerve** (fig. 939) is the smallest branch of the ophthalmic nerve. It sometimes receives a filament from the trochlear nerve, but possibly this filament consists of fibres which have previously passed from the ophthalmic to the trochlear nerve. The lacrimal nerve enters the orbit through the lateral part of the superior orbital fissure, runs along the upper border of the rectus lateralis with the lacrimal artery, and receives a twig from the zygomatic branch of the maxillary nerve, conveying some secretomotor fibres for the lacrimal gland. It enters the lacrimal gland and gives off several filaments to the gland and the conjunctiva. Finally it pierces the orbital septum, and ends in the skin of the upper eyelid, joining with filaments of the facial nerve.

The lacrimal nerve is occasionally absent, and its place is then taken by the zygomaticotemporal branch of the maxillary nerve. Sometimes the latter branch is absent and a continuation of the lacrimal is substituted for it.

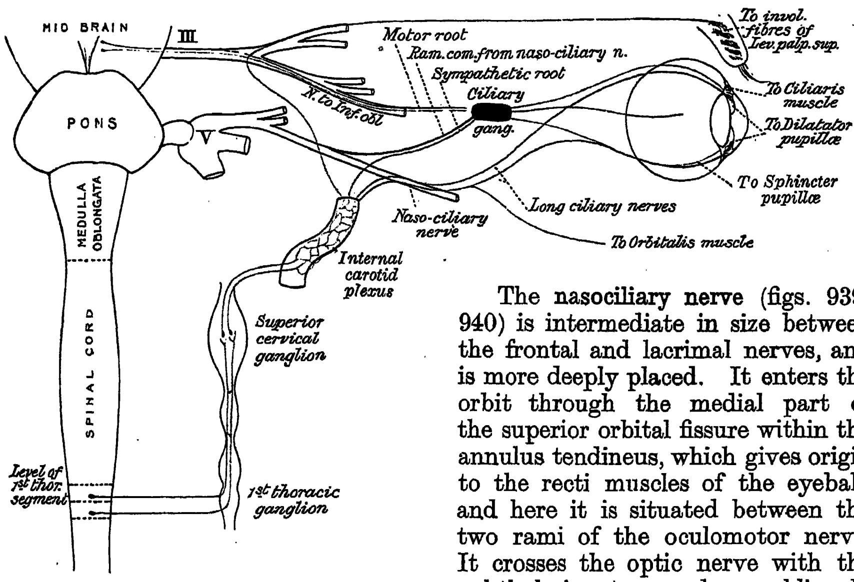
The **frontal nerve** (figs. 939, 940) is the largest branch of the ophthalmic nerve. It enters the orbit through the superior orbital fissure above the muscles, and runs forwards between the levator palpebræ superioris and the periosteum. About midway between the apex and base of the orbit it divides into a small supratrochlear and a large supra-orbital branch.

The *supratrochlear nerve* runs medially and forwards, passes above the pulley of the obliquus superior, and gives off a descending filament to join the infratrochlear branch of the nasociliary nerve. The nerve then emerges

from the orbit between the pulley of the obliquus superior and the supra-orbital foramen, curves upwards on the forehead close to the bone in company with the supratrochlear branch of the ophthalmic artery, and sends filaments to the conjunctiva and skin of the upper eyelid; it then ascends under cover of the corrugator and the frontal belly of the occipitofrontalis, and divides into branches which pierce these muscles and supply the skin of the lower part of the forehead close to the median plane.

The *supra-orbital nerve* runs forwards between the levator palpebræ superioris and the roof of the orbit, passes through the supra-orbital notch or foramen, and gives off palpebral filaments to the upper eyelid and conjunctiva. It then ascends upon the forehead with the supra-orbital artery, and divides into a smaller medial and a larger lateral, branch, which supply the skin of the scalp, reaching nearly as far back as the lambdoid suture. These two branches are at first situated deep to the frontal belly of the occipitofrontalis; the medial branch perforates this muscle, the lateral branch pierces the epicranial aponeurosis. Both branches supply small twigs to the mucous membrane of the frontal sinus and to the pericranium.

FIG. 941.—A scheme showing the roots and the branches of distribution of the ciliary ganglion.



The **nasociliary nerve** (figs. 939, 940) is intermediate in size between the frontal and lacrimal nerves, and is more deeply placed. It enters the orbit through the medial part of the superior orbital fissure within the annulus tendineus, which gives origin to the recti muscles of the eyeball, and here it is situated between the two rami of the oculomotor nerve. It crosses the optic nerve with the ophthalmic artery, and runs obliquely below the rectus superior and obliquus superior, to the medial wall of the orbital cavity. Here, under the name of the *anterior ethmoidal nerve*, it passes through the anterior ethmoidal foramen and canal and, entering the cavity of the cranium, traverses a shallow groove on the lateral margin of the front part of the cribriform plate of the ethmoid bone, beneath the dura mater; it then descends through a slit at the side of the crista galli into the nasal cavity, and lies in a groove on the inner surface of the nasal bone. It supplies two *internal nasal branches*—a medial to the mucous membrane of the front part of the nasal septum, and a lateral to the anterior part of the lateral wall of the nasal cavity. Finally it emerges, as the *external nasal branch*, between the lower border of the nasal bone and the upper nasal cartilage, and, passing down under cover of the compressor naris muscle, supplies the skin of the ala, the apex and the vestibule of the nose.

The nasociliary nerve gives off a communicating branch to the ciliary ganglion, the long ciliary, the infratrochlear and the posterior ethmoidal nerves.

The *ramus communicans to the ciliary ganglion* usually arises from the nasociliary nerve as the latter enters the orbital cavity. It passes forwards on the lateral side of the optic nerve, and enters the posterosuperior angle of the

ciliary ganglion ; it is sometimes joined by a filament from the internal carotid plexus of the sympathetic, or from the superior ramus of the oculomotor nerve.

The *long ciliary nerves*, two or three in number, are given off from the nasociliary nerve, as it crosses the optic nerve. They accompany the short ciliary nerves from the ciliary ganglion, pierce the sclera near the attachment of the optic nerve, and, running forwards between the sclera and the choroid, are distributed to the ciliary body, iris and cornea; they usually contain the sympathetic fibres for the dilatator pupillæ.

The *infratrochlear nerve* is given off from the nasociliary nerve near the anterior ethmoidal foramen. It runs forwards along the medial wall of the orbit above the upper border of the rectus medialis, and is joined, near the pulley of the obliquus superior, by a filament from the supratrochlear nerve. It then escapes from the orbit below the pulley of the obliquus superior ; it supplies branches to the skin of the eyelids and side of the nose above the medial angle of the eye, the conjunctiva, lacrimal sac and caruncula lacrimalis.

The *posterior ethmoidal nerve* leaves the orbital cavity through the posterior ethmoidal foramen and gives twigs to the ethmoidal and sphenoidal sinuses. This nerve is absent in about thirty per cent. of subjects.

The **ciliary ganglion** (figs. 938, 940, 941) is a small, flattened ganglion, of a reddish-grey colour, and about the size of a pin's head; it is situated near the apex of the orbit, in some loose fat between the optic nerve and the rectus lateralis muscle, lying generally on the lateral side of the ophthalmic artery.

Its *connexions* (fig. 941) are three in number, and enter it posteriorly. A ramus communicans is derived from the nasociliary nerve. The motor root which is a thick nerve (occasionally divided into two parts) is derived from the branch of the oculomotor nerve to the obliquus inferior. The third, the sympathetic root, is a slender filament from the internal carotid plexus of the sympathetic ; it is frequently blended with the ramus communicans from the nasociliary nerve.

Its *branches* are the short ciliary nerves. These are delicate filaments, from six to ten in number, which arise from the front of the ganglion in two bundles, of which the lower bundle is the larger. They run forwards with the ciliary arteries in a wavy course, one set above the optic nerve, the other below, and are related to the long ciliary nerves. They subdivide into about fifteen or twenty branches, which pierce the sclera around the entrance of the optic nerve, pass forwards in delicate grooves on the inner surface of the sclera, and are distributed to the ciliary muscle, iris and cornea.

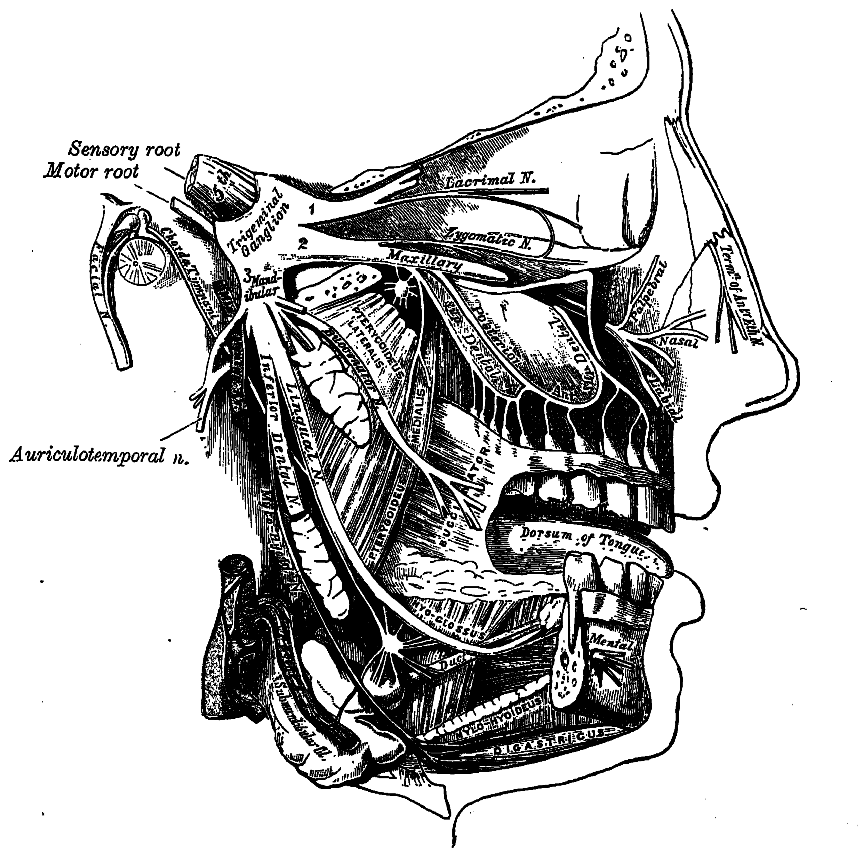
The Maxillary Nerve (fig. 942)

The **maxillary nerve**, or second division of the trigeminal nerve, is a sensory nerve, and is intermediate in position and size between the ophthalmic and mandibular nerves. It begins at the middle of the trigeminal ganglion as a flattened plexiform band, and, passing horizontally forwards along the lower part of the lateral wall of the cavernous sinus, leaves the skull through the foramen rotundum, where it becomes more cylindrical in form and firmer in texture. It then crosses the upper part of the pterygopalatine fossa, inclines laterally on the posterior surface of the orbital process of the palatine bone and on the upper part of the posterior surface of the maxilla, and enters the orbit through the inferior orbital fissure. It is now named the **infra-orbital nerve** and, having traversed the infra-orbital groove and canal in the floor of the orbit, it appears on the face through the infra-orbital foramen. At its termination the nerve lies under cover of the levator labii superioris, and divides into branches which are distributed to the side of the nose, the lower eyelid, the skin and mucous membrane of the cheek and upper lip, and join with filaments of the facial nerve.

In view of the fact that the mouth is generally regarded as representing a pair of fused visceral clefts, the maxillary nerve can be described as the pretrematic

and the mandibular nerve as the post-trematic branch of the trigeminal nerve. The maxillary nerve supplies the structures derived from the maxillary process, but it extends on to structures which are developed from the median nasal process and its fused globular processes (p. 94).

FIG. 942.—The right maxillary and mandibular nerves, and the submandibular ganglion.



The *branches* of the maxillary nerve may be divided into four groups, according as they are given off in the cranium, in the pterygopalatine fossa, in the infra-orbital canal, or on the face.

In the cranium . . .	Meningeal.
In the pterygopalatine fossa .	Zygomatic. Ganglionic. Posterior superior dental.
In the infra-orbital canal .	Middle superior dental. Anterior superior dental.
On the face	Palpebral. Nasal. Labial.

The **meningeal nerve** is given off from the maxillary nerve near the trigeminal ganglion; it accompanies the anterior branch of the middle meningeal artery and supplies the dura mater of the middle cranial fossa.

The **zygomatic nerve** (fig. 940) arises in the pterygopalatine fossa, enters the orbit by the inferior orbital fissure, courses along the lateral wall of the orbit, and divides into two branches, zygomaticotemporal and zygomatico-facial.

The *zygomaticotemporal branch* runs along the lateral wall of the orbit, sends a branch to join the lacrimal nerve (p. 1044), and, passing through a canal in the zygomatic bone, enters the temporal fossa. It ascends between the bone and the temporalis muscle, pierces the temporal fascia about 2 cm. above the zygomatic arch, and is distributed to the skin of the temple. It communicates with the facial nerve and with the auriculotemporal branch of the mandibular nerve. As it pierces the temporal fascia, it sends a slender twig between the two layers of the fascia towards the lateral angle of the eye.

The *zygomaticofacial branch* passes along the inferolateral angle of the orbit, emerges upon the face through a foramen in the zygomatic bone, and, perforating the orbicularis oculi, supplies the skin on the prominence of the cheek. It joins the zygomatic branches of the facial nerve and the palpebral branches of the maxillary nerve.

The **ganglionic branches** (sphenopalatine nerves), two in number, descend towards the sphenopalatine ganglion, but only a few of their fibres enter the ganglion.

The **posterior superior dental (alveolar) branches** (fig. 942) arise from the maxillary nerve just before it enters the infra-orbital groove; they are generally two in number, but sometimes they arise by a single trunk. They descend on the posterior surface of the maxilla and give off twigs to the gums and adjoining parts of the mucous membrane of the cheek. They then enter the posterior dental canals on the posterior surface of the maxilla, and, passing forwards in the substance of the bone, communicate with the middle superior dental nerve, and give off branches to the lining membrane of the maxillary sinus and twigs to each molar tooth; these twigs enter the foramina at the apices of the roots of the teeth.

The **middle superior dental (alveolar) branch** is given off from the infra-orbital nerve in the posterior part of the infra-orbital canal, and runs downwards and forwards in a canal in the lateral wall of the maxillary sinus to supply the two premolar teeth. It forms a superior dental plexus with the anterior and posterior superior dental branches.

The **anterior superior dental (alveolar) branch** (fig. 942) leaves the lateral side of the infra-orbital nerve in the front part of the infra-orbital canal, and runs in a canal in the anterior wall of the maxillary sinus. At first it curves beneath the infra-orbital foramen and passes medially towards the nose; it then turns downwards and divides into branches which supply the incisor and canine teeth. It communicates with the middle superior dental branch, and gives off a *nasal branch*, which passes through a minute canal in the lateral wall of the inferior meatus, and supplies the mucous membrane of the anterior part of the inferior meatus and the floor of the nasal cavity, communicating with the nasal branches from the sphenopalatine ganglion.

The **palpebral branches** ascend behind the orbicularis oculi. They supply the skin and conjunctiva of the lower eyelid, and join with the facial and zygomaticofacial nerves near the lateral angle of the eye.

The **nasal branches** supply the skin of the side of the nose and of the movable part of the nasal septum, and join with the external nasal branch of the anterior ethmoidal nerve.

The **labial branches** are large and numerous; they descend behind the levator labii superioris, and supply the skin of the anterior part of the cheek, the skin of the upper lip, the mucous membrane of the mouth, and the labial glands. They are joined by branches from the facial nerve, and form with them the *infra-orbital plexus*.

The **sphenopalatine ganglion** (fig. 943) is the largest of the ganglia associated with the branches of the trigeminal nerve, and is deeply placed in the pterygopalatine fossa, close to the sphenopalatine foramen and in front of the pterygoid canal. It is somewhat flattened, of a reddish-grey colour, and is situated just below the maxillary nerve as it crosses the fossa. It receives ganglionic branches from the maxillary nerve, and sympathetic and, probably, parasympathetic branches from the nerve of the pterygoid canal (fig. 943).

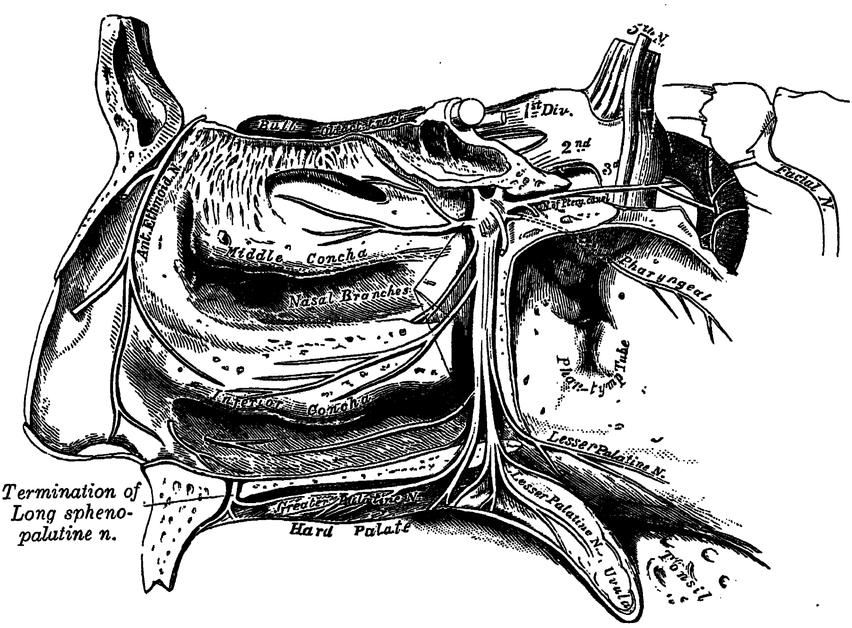
Most of the fibres conveyed by the *ganglionic branches* are not relayed in the ganglion but pass directly into the palatine and nasal nerves which spring from the ganglion.

The *nerve of the pterygoid canal* is formed by the union of the greater superficial petrosal and the deep petrosal nerve.

The *greater superficial petrosal nerve* is given off from the (genicular) ganglion of the facial nerve; it receives a branch from the tympanic plexus, passes through the hiatus on the anterior surface of the petrous part of the temporal bone, and runs forwards beneath the dura mater in a groove on the bone. It traverses the fibrocartilage which fills the foramen lacerum, and there unites with the deep petrosal nerve to form the *nerve of the pterygoid canal.*

The *deep petrosal nerve* is given off from the carotid sympathetic plexus, and runs through the carotid canal lateral to the internal carotid artery. It then enters the fibrocartilage which fills the foramen lacerum, and joins with the greater superficial petrosal nerve to form the nerve of the pterygoid canal.

FIG. 943.—The right sphenopalatine ganglion and its branches.



The *nerve of the pterygoid canal* runs forward through the pterygoid canal, where it is accompanied by the corresponding artery, and is joined by a small ascending branch from the otic ganglion. Finally, it enters the pterygopalatine fossa and joins the sphenopalatine ganglion.

The *branches* of the sphenopalatine ganglion are divisible into four groups, viz. orbital, palatine, nasal, and pharyngeal.

The *orbital branches* are two or three delicate filaments which enter the orbit by the inferior orbital fissure, and are distributed to the periosteum and the orbitalis muscle; some twigs pass through the posterior ethmoidal foramen to the sphenoidal and ethmoidal sinuses, and others are said to convey some of the secretomotor fibres to the lacrimal gland.

The *palatine nerves* (fig. 943) are distributed to the roof of the mouth, the soft palate, the tonsil, and the lining membrane of the nasal cavity. Most of their fibres are derived from the ganglionic branches of the maxillary nerve.

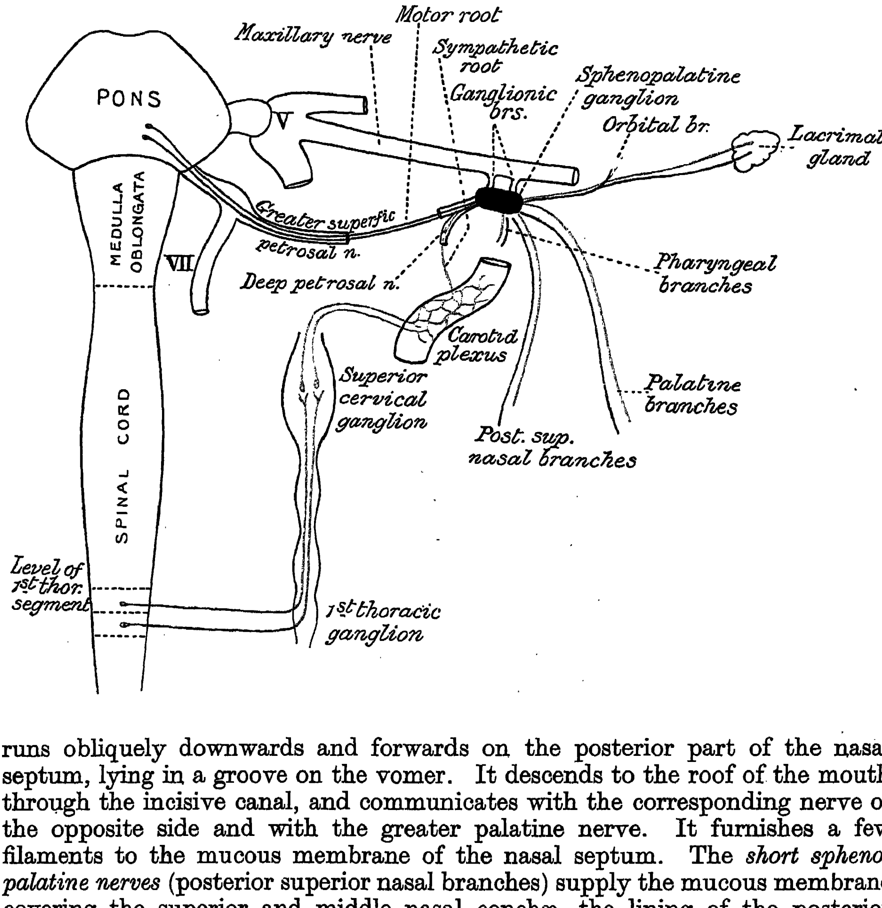
The *greater palatine nerve* (anterior palatine nerve) descends through the greater palatine canal (pterygopalatine canal), emerges upon the hard palate through the greater palatine foramen, and runs forwards in a groove on the inferior surface of the bony palate, nearly as far as the incisor teeth. It supplies the gums, and the mucous membrane and glands of the hard palate, and communicates in front with terminal filaments of the long sphenopalatine (naso-

palatine) nerve. While in the greater palatine canal, it gives off *nasal branches*, which emerge through openings in the perpendicular plate of the palatine bone, and ramify over the inferior nasal concha and the walls of the middle and inferior meatuses ; at its exit from the canal, palatine branches are distributed to both surfaces of the soft palate.

The *lesser palatine nerves* (middle and posterior palatine nerves) descend through the greater palatine canal, emerge through the lesser palatine foramina and supply branches to the uvula, tonsil and soft palate.

The long and short sphenopalatine nerves enter the nasal cavity through the sphenopalatine foramen. The *long sphenopalatine* (nasopalatine) *nerve* crosses the roof of the nasal cavity below the orifice of the sphenoidal sinus, and then

Fig. 944.—A scheme showing the roots and the branches of distribution of the sphenopalatine ganglion.



runs obliquely downwards and forwards on the posterior part of the nasal septum, lying in a groove on the vomer. It descends to the roof of the mouth through the incisive canal, and communicates with the corresponding nerve of the opposite side and with the greater palatine nerve. It furnishes a few filaments to the mucous membrane of the nasal septum. The *short sphenopalatine nerves* (posterior superior nasal branches) supply the mucous membrane covering the superior and middle nasal conchæ, the lining of the posterior ethmoidal sinuses and the posterior part of the nasal septum.

The *pharyngeal nerve*, a small branch, arises from the posterior part of the ganglion, passes through the palatinovaginal (pharyngeal) canal with the pharyngeal branch of the maxillary artery, and is distributed to the mucous membrane of the nasal part of the pharynx, behind the pharyngotympanic (auditory) tube.

The Mandibular Nerve (figs. 942, 945)

The **mandibular nerve** supplies the teeth and gums of the mandible, the skin of the temporal region, part of the auricle, the lower lip, the lower part of the face, and the muscles of mastication ; it also supplies the mucous membrane

of the anterior two-thirds of the tongue and the floor of the mouth. It is the largest division of the trigeminal nerve, and is made up of two roots : a large, sensory root, which proceeds from the lateral part of the trigeminal (semilunar) ganglion and emerges almost immediately through the foramen ovale of the sphenoid bone ; and a small motor root (the motor part of the trigeminal) which passes below the ganglion, and unites with the sensory root, just outside the foramen ovale, where the nerve lies between the tensor palati muscle medially and the lateral pterygoid laterally. Immediately beyond the junction of the two roots the nerve sends off from its medial side the nervus spinosus and the nerve to the medial pterygoid muscle, and then divides into a small anterior and a large posterior trunk.

The **nervus spinosus** enters the skull through the foramen spinosum with the middle meningeal artery. It divides into two branches, anterior and posterior, which accompany the main divisions of the artery and supply the dura mater ; the posterior branch also supplies a twig to the mucous lining of the mastoid air-cells ; the anterior communicates with the meningeal branch of the maxillary nerve.

The **nerve to the medial pterygoid muscle** is a slender branch which enters the deep surface of the muscle; it gives one or two filaments to the otic ganglion.

The small anterior trunk gives off (*a*) a sensory branch named the buccal (buccinator) nerve, and (*b*) motor branches, viz. the masseteric, deep temporal and lateral pterygoid nerves.

The **buccal nerve** (buccinator nerve) (fig. 945) passes forwards between the two heads of the lateral pterygoid, and downwards beneath or through the lower part of the temporal muscle ; it emerges from under the anterior border of the masseter, and unites with the buccal branches of the facial nerve. It furnishes a branch to the lateral pterygoid during its passage through that muscle, and may give off the anterior deep temporal nerve. The buccal nerve supplies the skin over the anterior part of the buccinator muscle, and the mucous membrane lining its inner surface and the posterior part of the buccal surface of the gum.

The **masseteric nerve** (fig. 945) passes laterally, above the lateral pterygoid, in front of the mandibular articulation, and behind the tendon of the temporal muscle ; it crosses the posterior part of the mandibular notch with the masseteric artery, ramifies in the deep surface of the masseter, and gives a filament to the mandibular joint.

The **deep temporal nerves** are usually two in number, anterior and posterior. They pass above the upper border of the lateral pterygoid and enter the deep surface of the temporal muscle. The *posterior branch*, of small size, is placed at the posterior part of the temporal fossa, and sometimes arises in common with the masseteric nerve. The *anterior branch* is frequently given off from the buccal nerve, and then ascends over the upper head of the lateral pterygoid. A third, or intermediate, branch is often present.

The **nerve to the lateral pterygoid** enters the deep surface of the muscle. It may arise separately from the anterior division of the mandibular nerve, or in conjunction with the buccal nerve.

The large posterior trunk of the mandibular nerve is for the most part sensory, but receives a few filaments from the motor root. It divides into auriculotemporal, lingual and inferior dental (inferior alveolar) nerves.

The **auriculotemporal nerve** generally arises by two roots, which encircle the middle meningeal artery (fig. 942). It runs backwards under cover of the lateral pterygoid on the surface of the tensor palati and passes between the sphenomandibular ligament and the neck of the mandible. It then passes laterally behind the mandibular joint in relationship with the upper part of the parotid gland. Finally it ascends, posterior to the superficial temporal vessels, over the zygomatic arch, and divides into superficial temporal branches.

The auriculotemporal nerve communicates with the facial nerve and the otic ganglion. The branches to the facial nerve, usually two in number, pass forwards and laterally behind the neck of the mandible and join the facial nerve at the posterior border of the masseter. The filaments to the otic ganglion are derived from the roots of the auriculotemporal nerve close to their origin.

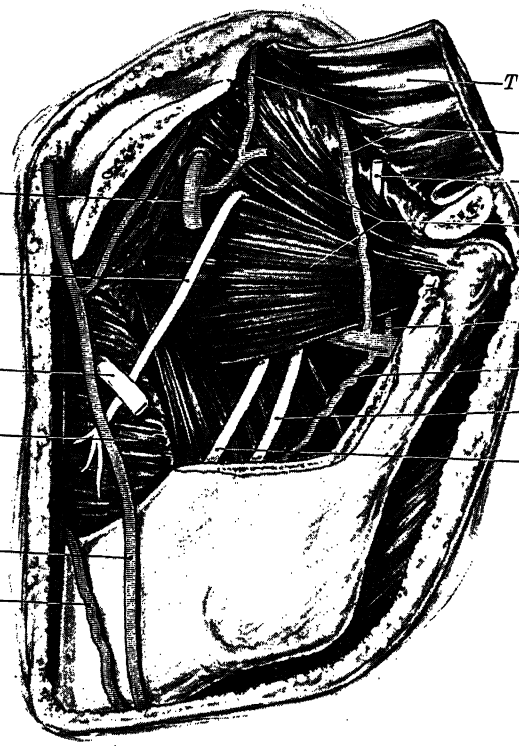
The *branches* of the auriculotemporal nerve are the anterior auricular, branches to the external auditory meatus, articular, parotid and superficial temporal.

The *auricular branches* are usually two in number: they supply the front of the upper part of the auricle, being distributed principally to the skin covering the front of the helix and tragus.

The *branches to the external auditory meatus*, two in number, pass between the bony and cartilaginous parts of the meatus, and supply the skin of the meatus; the upper one sends a twig to the tympanic membrane.

The *articular branches* consist of one or two twigs which enter the posterior part of the mandibular joint.

Fig. 945.—A dissection of the left pterygoid region, showing some of the branches of the mandibular nerve and the internal maxillary artery.



The *parotid branches* convey secretomotor fibres to the parotid gland. These are originally derived from the glossopharyngeal nerve and travel by the lesser superficial petrosal nerve and the otic ganglion to reach the auriculotemporal nerve.

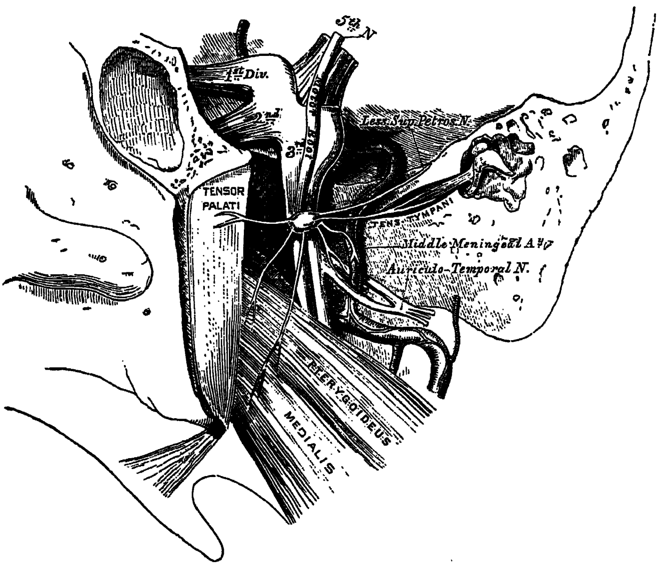
The *superficial temporal branches* accompany the superficial temporal artery and its terminal branches; they supply the skin of the temporal region and communicate with the facial and zygomaticotemporal nerves.

The **lingual nerve** (fig. 942) is sensory to the mucous membrane of the anterior two-thirds of the tongue, and to the floor of the mouth and the mandibular gums.

It arises from the posterior division of the mandibular nerve, and lies at first in relation with the deep surface of the lateral pterygoid muscle, where it is joined by the chorda tympani branch of the facial nerve, and frequently by a branch of the inferior dental nerve. Emerging from under cover of the lateral pterygoid muscle the lingual nerve proceeds downwards and forwards between the ramus of the mandible and the medial pterygoid muscle, lying anterior to, and slightly deeper than the inferior dental nerve. It then

passes below the mandibular origin of the superior constrictor of the pharynx, and lies against the deep surface of the mandible on the medial side of the roots of the third molar tooth, where it is covered only by the mucous membrane of the mouth. It next crosses the styloglossus, and runs on the lateral surface of the hyoglossus and deep to the mylohyoid muscle ; here it is placed above the deep part of the submandibular (submaxillary) gland and its duct. It then proceeds forwards on the side of the tongue, lying lateral to the hyoglossus and genioglossus, and divides into its terminal branches, which lie directly under cover of the mucous membrane of the tongue. In the latter part of its course the nerve is in close relation with the submandibular duct ; it passes from above downwards and forwards on the lateral side of the duct, and, then winding below it, runs upwards and forwards on its medial side.

FIG. 946.—The right otic ganglion and its branches displayed from the medial side.



In addition to receiving the chorda tympani and the branch from the inferior dental nerve, already referred to, the lingual nerve sends two or three branches to the submandibular (submaxillary) ganglion, and, at the anterior margin of the hyoglossus muscle, forms loops of communication with twigs of the hypoglossal nerve.

The *branches* of the lingual nerve supply the sublingual gland, the mucous membrane of the mouth, the lingual surface of the gums, and the mucous membrane of the anterior two-thirds of the tongue ; the terminal filaments join, at the tip of the tongue, with those of the hypoglossal nerve.

The **inferior dental nerve** descends with the inferior dental artery, at first under cover of the lateral pterygoid muscle, and then between the sphenomandibular ligament and the ramus of the mandible to the mandibular foramen. Here it enters the mandibular canal, and runs below the teeth as far as the mental foramen, where it divides into an incisive and a mental branch.

The inferior dental nerve gives off the mylohyoid nerve, branches to the molar and premolar teeth of the mandible, the incisive and the mental nerves.

The *mylohyoid nerve* is derived from the inferior dental nerve just before the latter enters the mandibular foramen. It pierces the sphenomandibular ligament, descends in a groove on the medial surface of the ramus of the mandible, and reaching the under surface of the mylohyoid supplies this muscle and the anterior belly of the digastric.

The branches to the molar and premolar teeth supply the adjoining gum also. Before they enter the roots of the teeth they communicate with one another and form an inferior dental plexus.

The *incisive branch* is continued onwards within the bone and supplies the canine and incisor teeth.*

The *mental nerve* emerges at the mental foramen, and divides beneath the depressor anguli oris muscle into three branches; one descends to the skin of the chin, and two ascend to the skin and mucous membrane of the lower lip; these branches communicate freely with the facial nerve (mandibular branch).

Two small ganglia, named the otic and the submandibular, are connected with the mandibular nerve.

The **otic ganglion** (figs. 946, 947) is a small, oval-shaped, flattened ganglion of a reddish-grey colour, situated immediately below the foramen ovale; it lies on the medial surface of the mandibular nerve, and surrounds the origin of the nerve to the medial pterygoid muscle. It is in relation *laterally* with the trunk of the mandibular nerve at the point where the motor and sensory roots join; *medially*, with the tensor palati, by which it is separated from the cartilaginous part of the pharyngotympanic (auditory) tube; *posteriorly*, with the middle meningeal artery.

It is connected by two or three short filaments with the nerve to the medial pterygoid muscle (fig. 947). It communicates with the glossopharyngeal and facial nerves, through the lesser superficial petrosal nerve continued from the tympanic plexus, and through this nerve receives parasympathetic roots from the glossopharyngeal nerve; its sympathetic roots are from the sympathetic plexus on the middle meningeal artery.

Branches.—A twig ascends from the otic ganglion to join the nerve of the pterygoid canal, and another connects the ganglion with the chorda tympani nerve. Two or more branches run backwards and join the roots of the auriculotemporal nerve; these branches probably carry secretomotor fibres from the glossopharyngeal nerve to the parotid gland. A filament is supplied to the tensor tympani muscle, and another to the tensor palati muscle. The former passes backwards, lateral to the pharyngotympanic tube; the latter arises from the ganglion, near the origin of the nerve to the medial pterygoid and is directed forwards. The fibres of the nerves to the tensor tympani and tensor palati are mainly derived from the nerve to the medial pterygoid muscle.

The **submandibular ganglion** (submaxillary ganglion) (figs. 942, 948) is small, and somewhat fusiform in shape. It is situated on the upper part of the hyoglossus, and deep to the posterior fibres of the mylohyoid muscle. Here it is placed above the deep part of the submandibular gland and below the lingual nerve, and is suspended from the latter by an anterior and a posterior filament. Through the posterior filament it receives fibres from the lingual and chorda tympani nerves. Sympathetic fibres are conveyed to the ganglion from the plexus on the cervical part of the facial artery (fig. 942).

Five or six branches arise from the ganglion, and supply the mucous membrane of the mouth, and the submandibular gland and its duct. Fibres pass through the filament connecting the fore part of the ganglion to the lingual nerve, and are conveyed to the sublingual gland and the tongue.

The mandibular nerve is distributed to the structures derived from the mandibular arch, and represents the post-trematic branch of the trigeminal nerve. The connexion of the nerve with the arch is indicated by: (1) its close relationship to the sphenomandibular ligament and the mandible; (2) its distribution to the anterior portion of the tongue; (3) its distribution to the anterosuperior part of the auricle; and (4) its union with the pretrematic nerve of the hyomandibular cleft, viz. the chorda tympani branch of the facial nerve.

Applied Anatomy.—A lesion of the whole trigeminal nerve causes anaesthesia of the corresponding anterior half of the scalp, of the face (excepting a small area near the angle of the mandible supplied by the great auricular nerve), of the cornea and conjunctiva, and of the mucous membranes of the nose, mouth and tongue. Paralysis and atrophy occur in the muscles supplied by the nerve and, when the mouth is opened the mandible is thrust

* According to C. Starkie and D. Stewart (*Journal of Anatomy*, vol. lxv. 1931), the nerves which supply the incisor teeth form an elaborate plexus on the external aspect of the mandible, after emerging from the mental foramen and before they enter the bone. The canine tooth may be supplied either from the incisor plexus or from the plexus which innervates the premolars.

FIG. 947.—A scheme showing the connexions and branches of the otic ganglion.

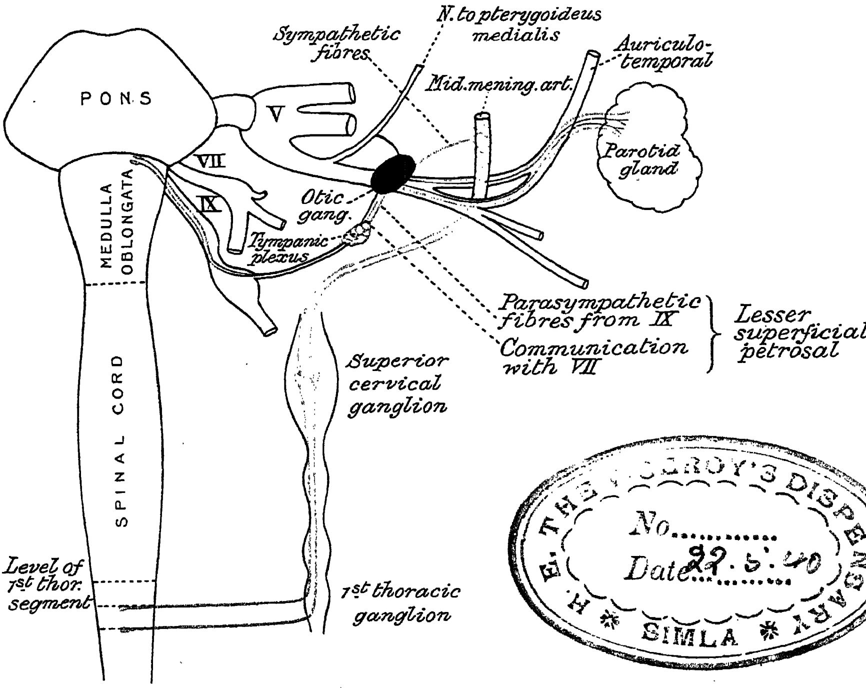
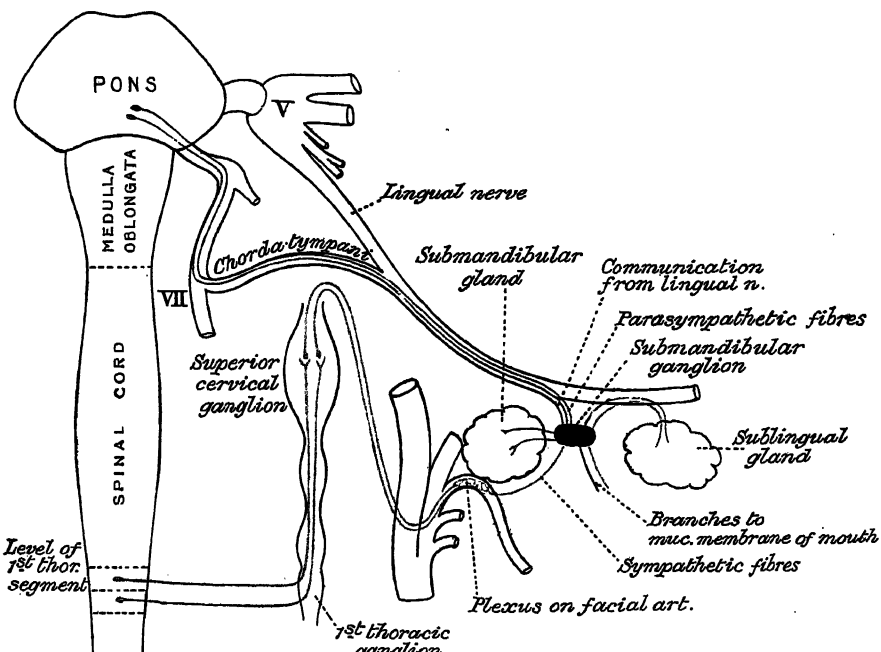


FIG. 948.—A scheme showing the connexions and branches of the submandibular ganglion.

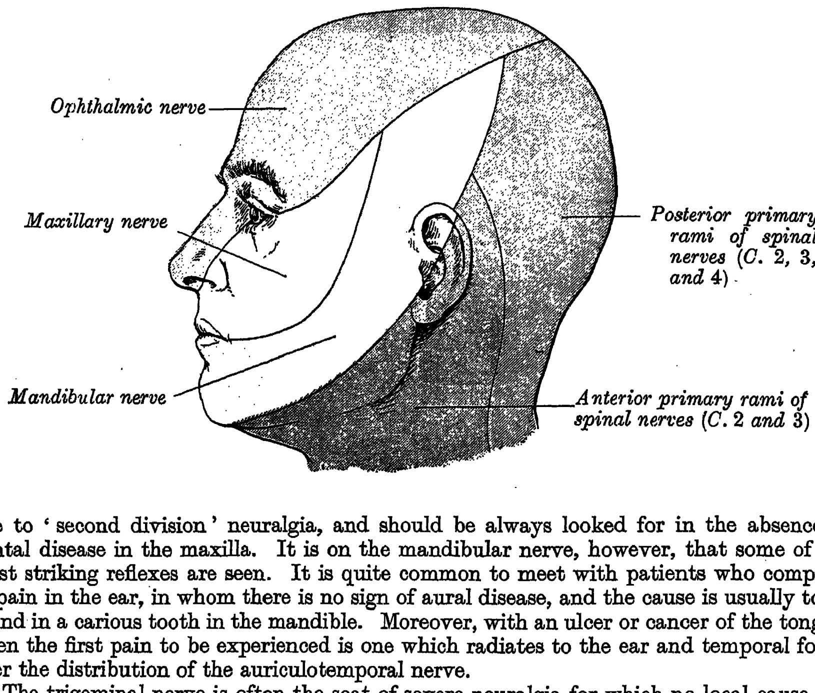


over to the paralysed side. Lesions of the divisions of the nerve give a more limited sensory loss and, if affecting the lingual nerve below the point at which it is joined by the chorda tympani, will be accompanied by loss of taste in the corresponding half of the anterior part of the tongue.

Trigeminal nerve reflexes.—Pains referred to various branches of the trigeminal nerve are of very frequent occurrence. As a general rule the diffusion of pain over the various branches of the nerve is at first confined to one only of the main divisions, although in severe cases pain may radiate over the branches of the other main divisions. The commonest example of this condition is the neuralgia which is so often associated with dental caries —here, although the tooth itself may not appear to be painful, the most distressing referred pains may be experienced, and these are at once relieved by treatment directed to the affected tooth.

Many other examples of trigeminal reflexes could be quoted, but it will be sufficient to mention the more common ones. In the area of the ophthalmic nerve, severe supra-orbital pain is commonly associated with acute glaucoma or with disease of the frontal or ethmoidal sinuses. Malignant growths or empyema of the maxillary sinus, or unhealthy conditions about the inferior conchæ or the septum of the nose, are often found giving

FIG. 949.—A diagram showing the cutaneous nerve-areas of the face and scalp.



rise to ' second division ' neuralgia, and should be always looked for in the absence of dental disease in the maxilla. It is on the mandibular nerve, however, that some of the most striking reflexes are seen. It is quite common to meet with patients who complain of pain in the ear, in whom there is no sign of aural disease, and the cause is usually to be found in a carious tooth in the mandible. Moreover, with an ulcer or cancer of the tongue, often the first pain to be experienced is one which radiates to the ear and temporal fossa, over the distribution of the auriculotemporal nerve.

The trigeminal nerve is often the seat of severe neuralgia for which no local cause can be discovered; each of the three divisions has been divided, or a portion of nerve excised for this affection, usually, however, with only temporary relief.

The lingual nerve is occasionally divided with a view to relieving the pain in cancerous disease of the tongue. This may be done in that part of its course where it lies below and behind the last molar tooth. If a line be drawn from the middle of the crown of the last molar tooth to the angle of the mandible it will cross the nerve, which lies about 1·25 cm. behind the tooth, parallel to the bulging alveolar ridge on the inner side of the body of the bone.

In severe cases of neuralgia of the trigeminal nerve, the trunks of the maxillary and mandibular nerves may be injected with alcohol; if this treatment fails the trigeminal ganglion may be removed in whole or in part, or the sensory root of the nerve may be divided. Attempts at avulsion of the whole ganglion, however, frequently result in death owing to laceration of the cavernous sinus during the exposure and separation of the ophthalmic nerve from the ganglion. In cases where the neuralgia has been limited to the maxillary nerve intracranial resection of that nerve alone has been performed with great success. In other cases where the disease has not affected the ophthalmic division, resection of the lateral half of the ganglion only, with the maxillary and mandibular nerves, has been performed, thus leaving the sensory nerve supply to the cornea intact. The motor

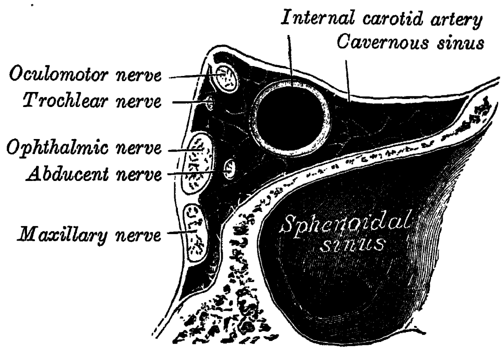
root is usually resected with the mandibular nerve, leading to complete paralysis of the muscles of mastication on that side. In the most recent operation the sensory root is divided behind the trigeminal ganglion; the motor root may in this way be left intact.

The Abducent Nerve (fig. 940)

The **abducent nerve** supplies the lateral rectus muscle of the eyeball.

Its fibres arise from a small nucleus which is situated in the upper part of the floor of the fourth ventricle, close to the median plane and beneath the colliculus facialis. They pass downwards and forwards through the pons, and emerge in the furrow between the lower border of the pons and the upper end of the pyramid of the medulla oblongata.

Fig. 950.—An oblique section through the left cavernous sinus. Posterior aspect.



The **nucleus** of the abducent nerve represents the somatic efferent column and retains its primitive position close to the median plane (p. 910).

Connexions.—The nucleus of the abducent nerve receives fibres from: (1) the pyramidal tract of the opposite side; (2) the medial longitudinal bundle, by which it is connected with the nuclei of the third, fourth and eighth cranial nerves; and (3) the tectobulbar tract, by which it is connected with the visual cortex through the medium of the superior quadrigeminal body.

After leaving the surface of the brain-stem, the abducent nerve runs upwards, forwards and laterally through the cisterna pontis, and usually dorsal to the anterior inferior cerebellar artery. It pierces the dura mater lateral to the dorsum sellæ of the sphenoid bone and then bends sharply forwards as it crosses the superior border of the petrous part of the temporal bone close to its apex. In this situation it passes below the petrosphenoidal ligament—a fibrous band which connects the lateral margin of the dorsum sellæ to the upper border of the petrous part of the temporal bone near its medial end. It next traverses the cavernous sinus, lying at first lateral and then inferolateral to the internal carotid artery, and enters the orbital cavity through the medial part of the superior orbital fissure. It passes within the common tendinous ring from which the recti muscles of the eyeball arise, lying below the oculomotor and nasociliary nerves, and finally sinks into the ocular surface of the lateral rectus.

In the cavernous sinus the abducent nerve is joined by several filaments from the internal carotid plexus, and communicates with the ophthalmic nerve.

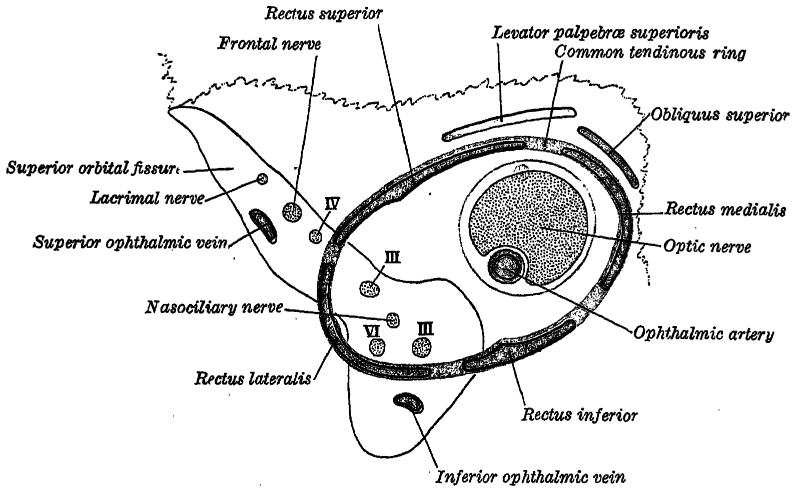
The oculomotor, trochlear, ophthalmic and abducent nerves bear certain relations to each other in the cavernous sinus, at the superior orbital fissure, and in the cavity of the orbit, as follows.

In the *cavernous sinus* (fig. 950), the oculomotor, trochlear and ophthalmic nerves are placed in the lateral wall of the sinus, in the order given, from above downwards; the abducent nerve lies at the lateral side of the internal carotid artery. As these nerves pass forwards to the superior orbital fissure, the oculomotor and ophthalmic nerves divide into branches, and the abducent nerve approaches the others; so that their relative positions are considerably changed.

In the *superior orbital fissure* (fig. 951), the trochlear nerve and the frontal and lacrimal divisions of the ophthalmic nerve lie in this order from the medial to the lateral side upon the same plane; they enter the cavity of the orbit above the muscles. The remaining nerves enter the orbit within the common tendinous ring. The superior division of the oculomotor nerve is the highest of these, and is separated from the inferior division by the nasociliary nerve (fig. 951); the abducent nerve is placed on the lateral side of the inferior division of the oculomotor nerve.

In the *orbit* (fig. 939) the trochlear, frontal and lacrimal nerves lie immediately below the periosteum; the trochlear nerve at once enters the obliquus

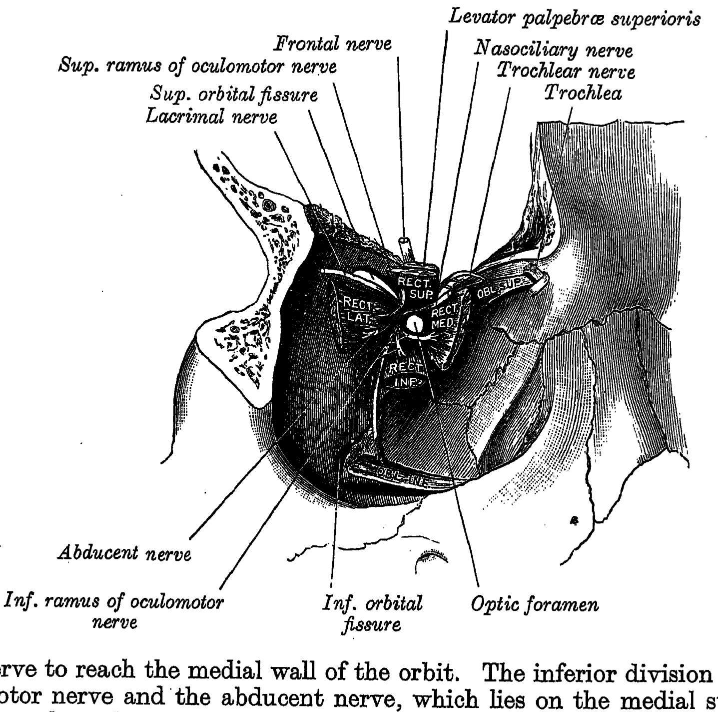
Fig. 951.—Scheme to show the common tendinous ring, the origins of the Recti, and the relative positions of the nerves entering the orbital cavity through the superior orbital fissure. (Modified from a figure in Whitnall's *Anatomy of the Human Orbit*; Oxford Medical Publications.)



The ophthalmic veins often pass through the common tendinous ring.

superior, the frontal lies on the levator palpebræ superioris, and the lacrimal on the rectus lateralis. The superior division of the oculomotor nerve lies immediately below the rectus superior, while the nasociliary nerve crosses the optic

Fig. 952.—A dissection showing the origins of the right ocular muscles, and the nerves entering the orbit through the superior orbital fissure.



nerve to reach the medial wall of the orbit. The inferior division of the oculomotor nerve and the abducent nerve, which lies on the medial surface of the rectus lateralis, lie below the optic nerve.

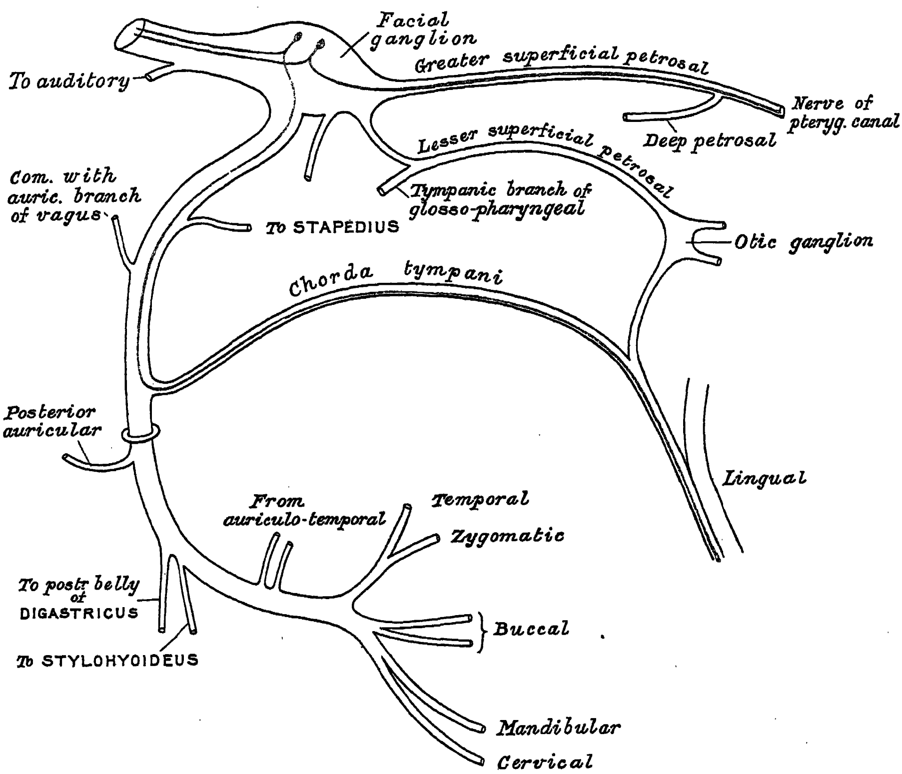
Applied Anatomy.—The abducent nerve is occasionally involved in fractures of the base of the skull. The result of paralysis of this nerve is medial or convergent squint. Diplopia

is also present. When injured so that its function is destroyed, there is, in addition to the paralysis of the rectus lateralis, often a certain amount of contraction of the pupil, because some of the sympathetic fibres to the dilatator pupillæ muscle are conveyed through this nerve.

The Facial Nerve (figs. 953 to 956)

The **facial nerve** consists of a motor and a sensory root (*nervus intermedius*) (fig. 836). The two roots appear at the lower border of the pons just lateral to the recess between the olive and the inferior cerebellar peduncle (restiform body), the motor part being the more medial; the auditory nerve lies immediately to the lateral side of the sensory.

Fig. 953.—A plan of the facial nerve. The course of the sensory fibres is represented by the blue lines.



The motor part supplies the muscles of the face, scalp, and auricle, the buccinator, platysma, stapedius, stylohyoid, and posterior belly of the digastric and the secretomotor fibres for the submandibular (submaxillary) and sublingual salivary glands and for the lacrimal gland; the sensory part conveys from the chorda tympani nerve the fibres of taste for the anterior two-thirds of the tongue, and from the palatine and greater superficial petrosal nerves the fibres of taste from the soft palate.

The **nucleus** from which most of the motor fibres of the facial nerve are derived lies deeply in the reticular formation of the lower part of the pons. It is situated behind the dorsal nucleus of the corpus trapezoideum (superior olivary nucleus) and ventrimedial to the nucleus of the spinal tract of the trigeminal nerve. It represents the branchial (special visceral) efferent column, but it lies much more deeply in the pons than might be expected, and its outgoing fibres pursue a very unusual course. Both these features are explicable in accordance with the principle of neurobiotaxis (p. 911). The nucleus receives fibres from the pyramidal tract of the opposite side. In addition, some of the efferent fibres of the facial nerve take origin from the *superior salivary nucleus*, which lies in the reticular formation, dorsilateral to the caudal end of the motor

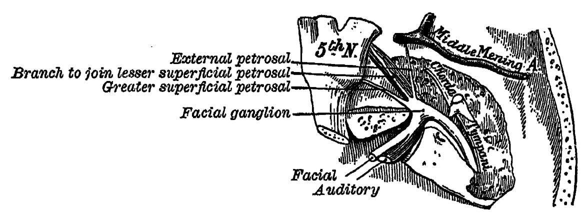
nucleus. It represents the general visceral efferent column, and it sends its fibres to join the motor root, by which they are ultimately distributed through the chorda tympani to the submandibular (submaxillary) and sublingual salivary gland.* From this double origin the fibres of the *motor root* pass backwards and medially, and, reaching the lower end of the nucleus of the abducent nerve, run upwards superficial to this nucleus beneath the colliculus facialis. At the upper end of the nucleus of the abducent nerve they make a second bend, and run downwards and forwards through the pons to their point of emergence between the olive and the inferior cerebellar peduncle (restiform body) (figs. 836, 851).

The **sensory nucleus** of the facial nerve is the upper part of the *nucleus of the tractus solitarius* of the medulla oblongata (p. 913). It receives afferent fibres from the sensory root and sends efferent fibres to the cortex, probably to the hippocampal gyrus in the neighbourhood of the uncus. Their pathway is unknown, but it is almost certain that they have a cell station in the thalamus.

The *sensory root* (nervus intermedius) consists of the central branches of the axons of the unipolar cells of the facial (geniculate) ganglion, which leave the trunk of the facial nerve in the internal auditory meatus and pass centrally, in close relation with the motor root and the auditory nerve, to enter the brain-stem at the lower border of the pons.

From their attachments to the brain, the two roots of the facial nerve pass laterally and forwards with the auditory nerve to the opening of the internal auditory meatus. In the meatus the motor root lies in a groove on the upper and anterior surface of the auditory nerve, the sensory root being placed between them.

FIG. 954.—The course and connexions of the facial nerve in the temporal bone.



At the bottom of the meatus, the facial nerve enters the facial canal. In this canal the nerve runs at first laterally above the vestibule, and reaching the medial wall of the epitympanic recess, bends suddenly backwards above the promontory, and arches downwards in the medial wall of the aditus to the tympanic antrum. Finally it descends to reach the stylomastoid foramen. The point where it bends suddenly backwards is named the *genu* ; it presents a reddish gangliform swelling, named the *ganglion of the facial nerve* (fig. 954). On emerging from the stylomastoid foramen, the facial nerve runs forwards in the substance of the parotid gland, crosses the styloid process and the external carotid artery, and divides behind the ramus of the mandible into branches which pierce the anteromedial surface of the parotid gland and diverge from one another under cover of it. They form a network (*parotid plexus*) and are distributed to the superficial muscles on the side of the head, face, and upper part of the neck.

The *branches of communication* of the facial nerve may be arranged as follows :

In the internal auditory meatus	With the auditory nerve.
At the facial ganglion .	With the sphenopalatine ganglion by the greater superficial petrosal nerve. With the otic ganglion by a branch which joins the lesser superficial petrosal nerve. With the sympathetic plexus on the middle meningeal artery.
In the facial canal . .	With the auricular branch of the vagus nerve.
At its exit from the stylomastoid foramen . .	With the glossopharyngeal, vagus, great auricular, and auriculotemporal nerves.
Behind the ear . . .	With the lesser occipital nerve.
On the face . . .	With the trigeminal nerve.
In the neck . . .	With the anterior cutaneous cervical nerve.

* The source of the secretomotor fibres to the lacrimal gland is uncertain.

In the internal auditory meatus some minute filaments pass from the facial nerve to the auditory nerve.

The *greater superficial petrosal nerve* arises from the ganglion of the facial nerve, and consists chiefly of taste fibres which are distributed to the mucous membrane of the soft palate ; but it probably contains a few parasympathetic fibres which are destined for the sphenopalatine ganglion and are there relayed through the zygomatic and lacrimal nerves (p. 1048) to the lacrimal gland. It receives a twig from the tympanic plexus, passes forwards through the hiatus on the anterior surface of the petrous portion of the temporal bone and runs in a groove on the bone. It passes beneath the trigeminal ganglion and reaches the foramen lacerum. In this foramen it is joined by the deep petrosal nerve from the sympathetic plexus on the internal carotid artery, and forms the nerve of the pterygoid canal, which passes forwards through the pterygoid canal and ends in the sphenopalatine ganglion. From the ganglion of the facial nerve a branch runs to join the lesser superficial petrosal nerve, and is conveyed through this nerve to the otic ganglion. The sympathetic plexus on the middle meningeal artery is joined to the ganglion of the facial nerve by an inconstant branch, sometimes named the *external petrosal nerve.*

Before the facial nerve emerges from the stylomastoid foramen, it receives a twig from the auricular branch of the vagus.

After its exit from the stylomastoid foramen, the facial nerve receives a twig from the glossopharyngeal nerve, and communicates with the great auricular and auriculotemporal nerves in the parotid gland, with the lesser occipital nerve behind the ear, with the terminal branches of the trigeminal nerve on the face, and with the anterior cutaneous cervical nerve in the neck.

The *branches of distribution* (figs. 953, 955) of the facial nerve may be grouped as follows :

Within the facial canal	Nerve to the stapedius muscle. Chorda tympani.
At its exit from the stylomastoid foramen	Posterior auricular. Digastric, posterior belly. Stylohyoid.
On the face	Temporal. Zygomatic. Buccal. Mandibular. Cervical.

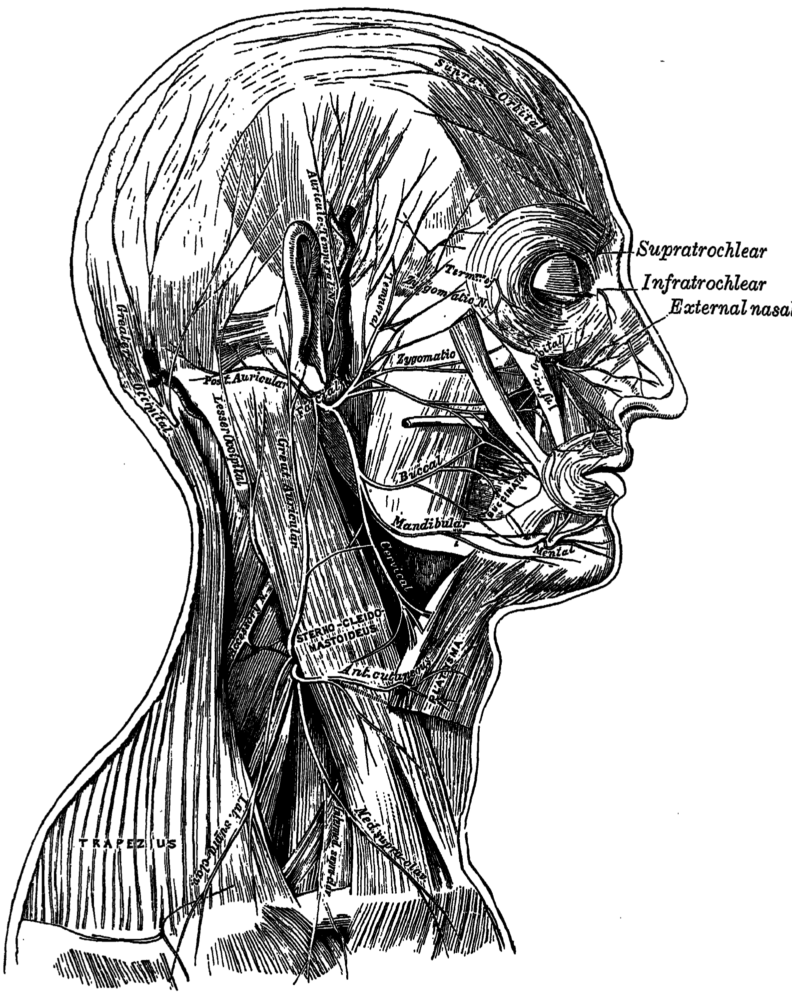
The **nerve to the stapedius** arises from the facial nerve opposite the pyramidal eminence on the posterior wall of the tympanic cavity ; it passes forwards through a small canal to reach the muscle.

The **chorda tympani nerve** (fig. 942) arises from the facial nerve about 6 mm. above the stylomastoid foramen. It runs upwards and forwards in a canal, and enters the tympanic cavity through the posterior canaliculus for the chorda tympani nerve, which is situated on its posterior wall, close to the posterior border of the medial surface of the tympanic membrane and on a level with the upper end of the manubrium of the malleus. It traverses the tympanic cavity, between the fibrous and mucous layers of the tympanic membrane, crosses the manubrium of the malleus, and leaves the cavity through the anterior canaliculus for the chorda tympani nerve, which is placed at the inner end of the petrotympanic fissure. The nerve now runs downwards and forwards on the medial surface of the spine of the sphenoid bone (which it sometimes grooves) and passes deep to the lateral pterygoid muscle. In this part of its course the nerve lies on the tensor palati and is crossed by the middle meningeal artery, the roots of the auriculotemporal nerve and the inferior dental nerve. Finally it joins the posterior border of the lingual nerve at an acute angle. It contains a few efferent secretomotor fibres which enter the submandibular (submaxillary) ganglion, which sends postganglionic fibres to the submandibular and sublingual glands ; the majority of its fibres are afferent, and are continued onwards through the muscular substance of the tongue to the mucous membrane covering its anterior two-thirds ; they constitute the nerve of taste for this portion of

the tongue. Before uniting with the lingual nerve the chorda tympani is joined by a small branch from the otic ganglion.

The **posterior auricular nerve** arises close to the stylomastoid foramen and runs upwards in front of the mastoid process ; here it is joined by a filament from the auricular branch of the vagus nerve, and communicates with the posterior branch of the great auricular nerve, and with the lesser occipital nerve. As it ascends between the external auditory meatus and the mastoid process it divides into an auricular and an occipital branch. The *auricular*

FIG. 955.—The nerves of the right side of the scalp, face, and neck.



branch supplies the auricularis posterior and the intrinsic muscles on the cranial surface of the auricle (pinna). The *occipital branch*, the larger, passes backwards along the superior nuchal line of the occipital bone, and supplies the occipital belly of the occipitofrontalis.

The **digastric branch** arises close to the stylomastoid foramen, and divides into several filaments which supply the posterior belly of the digastric ; one of these filaments joins the glossopharyngeal nerve.

The **stylohyoid branch**, long and slender, frequently arises in conjunction with the digastric branch ; it enters the middle part of the stylohyoid muscle.

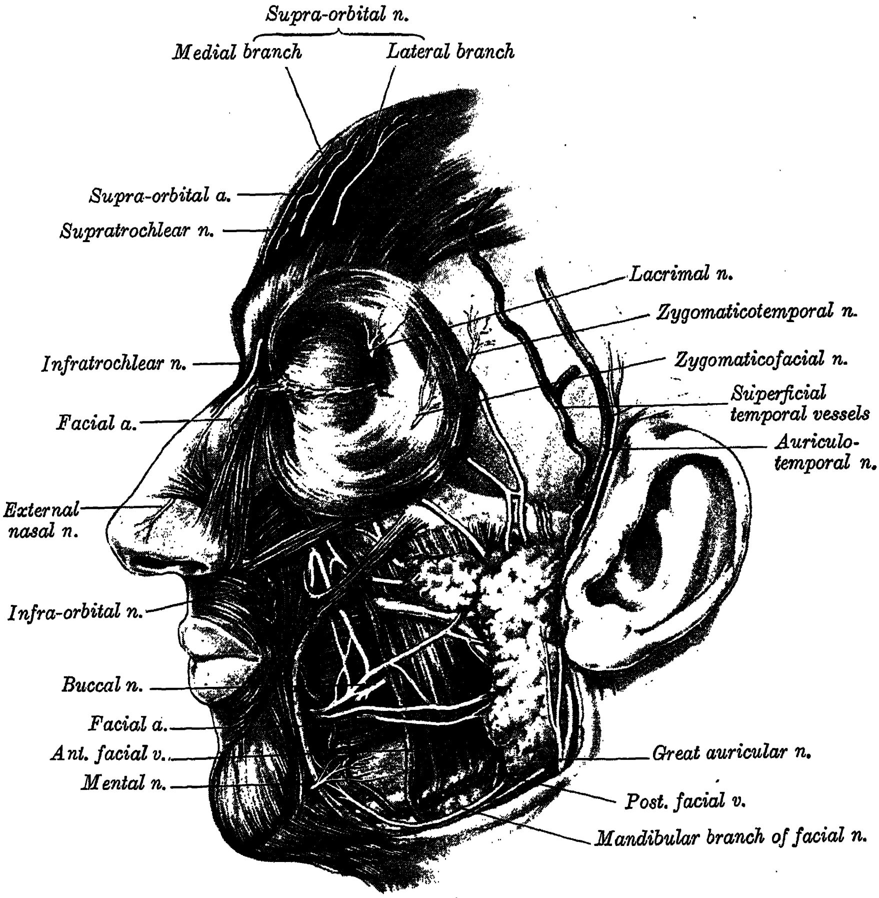
The **temporal branches** cross the zygomatic arch to the temporal region. They supply the intrinsic muscles on the lateral surface of the auricle, the anterior and superior auricular muscles, and join with the zygomaticotemporal branch of the maxillary nerve, and with the auriculotemporal branch of the

mandibular nerve. The more anterior branches supply the frontal belly of the occipitofrontalis, the orbicularis oculi and the corrugator, and join the supra-orbital and lacrimal branches of the ophthalmic nerve.

The **zygomatic branches** run across the zygomatic bone to the lateral angle of the eye; they supply the orbicularis oculi, and join with filaments of the lacrimal nerve and the zygomaticofacial branch of the maxillary nerve.

The **buccal branches** pass horizontally forwards to be distributed below the orbit and around the mouth. The *superficial branches* run between the skin of the face and the superficial muscles, and supply the latter; some are dis-

FIG. 956.—The cutaneous branches of the trigeminal nerve.



The branches of the facial nerve are seen emerging from the parotid gland.

tributed to the procerus, joining with the infratrochlear and external nasal nerves. The upper *deep branches* pass under cover of the zygomaticus major and the levator labii superioris, supplying them and forming an *infra-orbital plexus* with the superior labial branches of the infra-orbital nerve; they also supply the levator anguli oris, the zygomaticus minor, the levator labii superioris alæque nasi and the small muscles of the nose. These branches are sometimes described as lower zygomatic branches. The lower deep branches supply the buccinator and orbicularis oris, and join with filaments of the buccal branch of the mandibular nerve.

The **mandibular branch** runs forwards below the angle of the mandible under cover of the platysma. It lies at first superficial to the upper part of the digastric triangle and then turns upwards and forwards across the body of the mandible to lie under cover of the depressor anguli oris (triangularis) (fig. 956). It supplies the risorius and the muscles of the lower lip and chin, and joins the mental branch of the inferior dental nerve.

The **cervical branch** issues from the lower part of the parotid gland, runs forwards and downwards under cover of the platysma to the front of the neck. It supplies the platysma and communicates with the anterior cutaneous cervical nerve.

Applied Anatomy.—Facial palsy is commonly unilateral, and may be either: (1) *peripheral*, from lesion of the facial nerve; (2) *nuclear*, from destruction of the facial nucleus; or (3) *central, cerebral* or *supranuclear*, from injury in the brain to the fibres passing from the cortex through the internal capsule to the facial nucleus, or from injury to the face-area of the motor cortex itself. In supranuclear facial paralysis, which is usually part of a hemiplegia, it is the lower part of the face that is chiefly affected, while the forehead can be freely wrinkled on the palsied side, the eye can be closed fairly well and the eyeball is not rolled up under the upper lid; emotional movements of the face are executed much better than voluntary movements; and the electrical reactions of the muscles on the affected side are not altered. If the paralysis is due to lesion of the facial nucleus, the orbicularis oris escapes, as the nuclear origin of the nerve to this muscle seems to be connected with that of the tongue-nerves; otherwise the symptoms are identical with those of the common peripheral facial palsy, of which several types may be distinguished according to the point in its course at which the facial nerve is injured. If the lesion occurs (*a*) in the pons, facial paralysis is produced as in (*d*) below; taste and hearing are not affected, but the abducent nerve also will be paralysed because the fibres of the facial nerve loop round its nucleus in the pons. When the nerve is paralysed (*b*) in the petrous temporal, in addition to the paralysis of the motor nucleus, there is loss of taste in the anterior part of the tongue, and the patient is unable, from involvement of the chorda tympani, to recognise the difference between bitters and sweets, acids and salines: the sense of hearing is affected from paralysis of the stapedius. When the cause of the paralysis is (*c*) fracture of the base of the skull, the auditory and petrosal nerves are usually involved. But by far the commonest cause of facial palsy is (*d*) exposure of the nerve to cold or injury at or after its exit from the stylomastoid foramen (Bell's paralysis). In these cases the face looks asymmetrical even when at rest, and more so in the old than in the young. The affected side of the face and forehead remains motionless when voluntary or emotional movement is attempted. The lines on the forehead are smoothed out, the eye can be shut only by hand, tears fail to enter the lacrimal puncta because they are no longer in contact with the conjunctiva, the conjunctival reflex is absent, and efforts to close the eye merely cause the eyeball to roll upwards until the cornea lies under the upper lid. The tip of the nose is drawn over towards the sound side; the nasolabial fold is partially obliterated on the affected side, and the ala nasi does not move properly on respiration. The lips remain in contact on the paralysed side, but cannot be pursed for whistling; when a smile is attempted the angle of the mouth is drawn up on the unaffected side but on the affected side the lips remain nearly closed, and the mouth assumes a characteristic triangular form. During mastication food accumulates in the cheek, from paralysis of the buccinator, and dribbles or is pushed out from between the paralysed lips. On protrusion the tongue seems to be thrust over towards the palsied side, but verification of its position by reference to the incisor teeth will show that this is not really so. The platysma and the muscles of the auricle are paralysed; in severe cases the articulation of labials is impaired. The electrical reactions of the affected muscles are altered (reaction of degeneration), and the degree to which this alteration has taken place after a week or ten days gives a valuable guide to the prognosis. Most cases of Bell's palsy recover completely.

The facial nerve is at fault in cases of so-called 'histrionic spasm,' which consists in an almost constant and uncontrollable twitching of some or all of the muscles of the face. This twitching is sometimes so severe as to cause great discomfort and annoyance to the patient, and to interfere with sleep, and for its relief the facial nerve has been stretched.

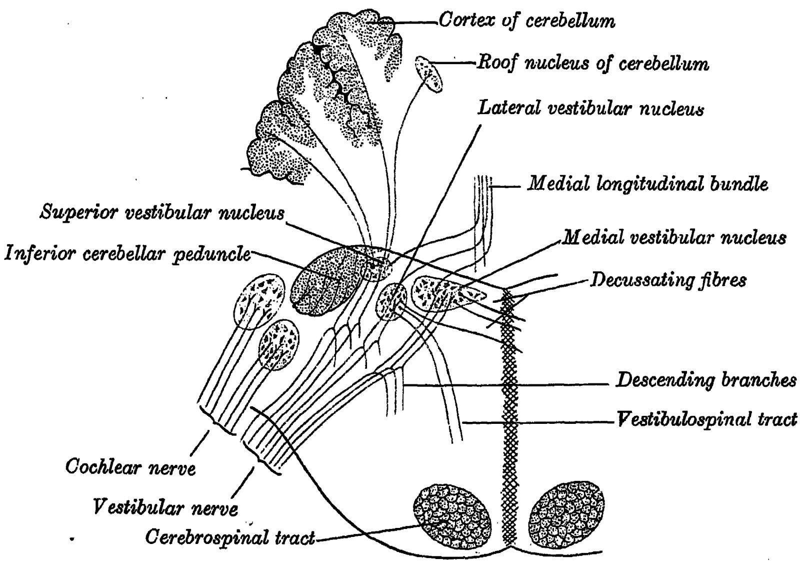
The Auditory Nerve

The **auditory nerve** (acoustic nerve) appears in the groove between the pons and medulla oblongata, behind the facial nerve and in front of the inferior cerebellar peduncle (restiform body) (fig. 836). It consists of two sets of fibres, which, although differing in their principal central connexions, are both concerned in the transmission of afferent impulses from the internal ear to the brain. One set of fibres forms the vestibular nerve, or nerve of equilibration, and arises from the cells of the vestibular ganglion situated in the bottom of the internal auditory meatus; the other set constitutes the cochlear nerve, or true nerve of hearing, and takes origin from the cells of the spiral ganglion of the cochlea. Both ganglia consist of bipolar nerve-cells, and from each cell a central fibre passes to the brain, and a peripheral fibre to the internal ear.

Vestibular nerve (fig. 957).—The fibres of the vestibular nerve enter the brain medial to those of the cochlear nerve and on a higher level. They pass backwards through the pons between the inferior cerebellar peduncle and the spinal tract of the trigeminal nerve and divide into ascending and descending branches which mostly end in the vestibular nuclei, although many proceed direct to the cerebellum along the inferior cerebellar peduncle.

The **vestibular nucleus** of termination comprises the following subdivisions: (1) The *medial vestibular nucleus* (p. 917), which lies in the vestibular area (area acustica) of the floor of the fourth ventricle, crossed dorsally by the auditory striæ (striæ medullares). It is the largest subdivision and extends upwards from the medulla oblongata into the pons. On transverse section it is triangular in outline. (2) The *inferior* (*spinal*) *vestibular nucleus* (p. 917) lies lateral to the medial nucleus and reaches to a lower level in the medulla oblongata. It is placed between the medial nucleus and the inferior cerebellar peduncle, and

FIG. 957.—The terminal nuclei and central connexions of the vestibular nerve. (Schematic.)



the descending branches of the incoming vestibular fibres are closely applied to its lateral aspect. (3) The *lateral nucleus* (p. 922) lies ventrilateral to the upper part of the medial nucleus, and it is characterised by the large size of its constituent cells. Its upper end inclines dorsally and becomes continuous with the lower end of (4) the *superior nucleus*, which extends higher into the pons than the other subdivisions and occupies the upper part of the vestibular area.

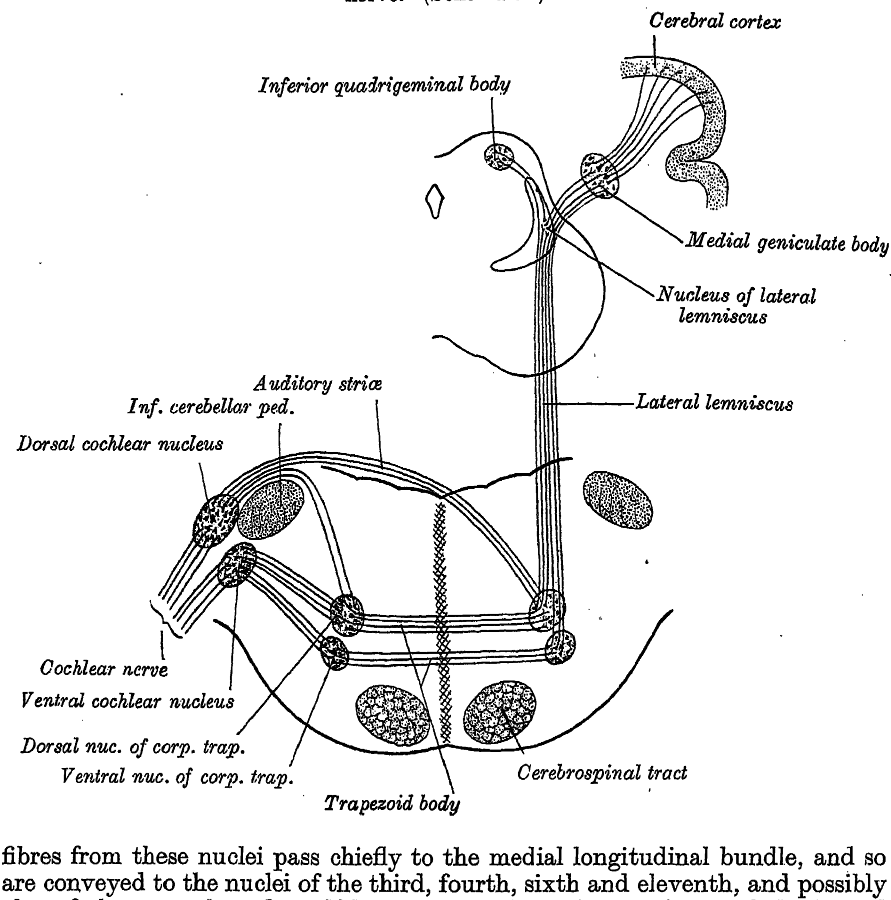
Connexions.—In addition to receiving afferent fibres from the vestibular nerve, the superior and lateral nuclei receive afferent fibres from the cerebellum, which travel by the inferior cerebellar peduncle.

The efferent fibres from the vestibular nuclei pass: (1) to the cerebellum, where they terminate in the cortex, including the flocculus; (2) to the medial longitudinal bundle (p. 949), by which they are conveyed to the nuclei of the third, fourth, sixth and eleventh cranial nerves and, by means of the anterior intersegmental tract, to the anterior grey column of the spinal cord; (3) to the vestibulospinal tract (p. 898), which arises chiefly from the large-celled lateral nucleus; and (4) to the corpus trapezoideum and the lateral lemniscus and so to the inferior quadrigeminal body.

Cochlear nerve (fig. 958).—As it reaches the brain-stem the cochlear nerve is placed on the lateral side of the vestibular nerve, but the two nerves soon become separated by the inferior cerebellar peduncle. The cochlear nerve passes round the lateral aspect of the peduncle, while the vestibular nerve penetrates the brain-stem on the medial side of that structure.

The **cochlear nuclei** are two in number. The *ventral cochlear nucleus* is placed on the ventrilateral aspect of the inferior cerebellar peduncle, and it receives the ascending branches of the cochlear nerve. The *dorsal cochlear nucleus* lies on the dorsal aspect of the peduncle in the lateral part of the vestibular area of the floor of the fourth ventricle, where it forms the auditory tubercle. It receives the descending branches of the cochlear nerve. The efferent fibres from the ventral cochlear nucleus run medially through the ventral part of the tegmentum of the pons and constitute the corpus trapezoideum. Having crossed the median plane they ascend in the lateral lemniscus (p. 922). In their course some of the trapezoidal fibres give off collaterals to, and others end in, the ventral and dorsal nuclei of the corpus trapezoideum. The efferent

FIG. 958.—The terminal nuclei and central connexions of the cochlear nerve. (Schematic.)



fibres from these nuclei pass chiefly to the medial longitudinal bundle, and so are conveyed to the nuclei of the third, fourth, sixth and eleventh, and possibly also of the seventh and twelfth cranial nerves. As the fibres of the lateral lemniscus ascend, some of them are interrupted in the nucleus of the lateral lemniscus and there relayed, many of them passing to the medial longitudinal bundle. Finally, the fibres of the lateral lemniscus terminate in the substantia nigra, the inferior quadrigeminal body and the medial geniculate body. From the last-named new fibres arise and pass through the retrolentiform part of the internal capsule to reach the auditosensory area of the cortex (p. 995).

The efferent fibres from the dorsal cochlear nucleus pass medially as the auditory striæ (striæ medullares) across the floor of the fourth ventricle. They pass forwards at the median sulcus, cross the median plane and then course forwards and laterally through the tegmentum to join the lateral lemniscus.

The auditory nerve is soft in texture, and is destitute of neurolemma in its proximal part.* After leaving the medulla oblongata it passes forwards across

* H. Alan Skinner, *British Journal of Surgery*, Jan. 1929.

the posterior border of the middle cerebellar peduncle, in company with the facial nerve, from which it is partially separated by the internal auditory artery. It then enters the internal auditory meatus with the facial nerve. At the bottom of the meatus it receives one or two filaments from the facial nerve, and splits into its *cochlear* and *vestibular* parts, the distribution of which will be described with the anatomy of the internal ear.

The cochlear and vestibular nuclei develop in the most dorsal part of the alar lamina, and the eighth nerve itself does not lie in series either with the ventral or with the dorsal cranial nerves (p. 1031). The mode of development of the cochlear and vestibular ganglia is consistent with this distinction, for their cells of origin are derived partly from the neural crest and partly from a dorsilateral ectodermal placode which is developed in association with the ectoderm of the auditory pit (p. 129). In fishes, a whole series of organs, termed lateral line organs or neuromasts, develops both in the head and in the trunk for the reception of vibration waves. These sense organs are very necessary for an aquatic life, but they disappear in terrestrial forms, leaving the auditory apparatus as their sole survivor. The auditory nerve, therefore, occupies a special position amongst the cranial nerves, and the olfactory nerve alone can be compared with it justifiably.

The vestibular and cochlear nerves, although apparently distinct, yet have much in common. The cochlear nerve, when it leaves the labyrinth and before it joins the vestibular nerve, carries with it fibres from the ampulla of the posterior semicircular duct and from the macula of the saccule. Winkler * has shown that some vestibular fibres run with the cochlear fibres on the lateral aspect of the inferior cerebellar peduncle and that some cochlear fibres terminate in the lateral vestibular nucleus. Vestibular fibres enter into the constitution of the corpus trapezoideum and may reach the inferior quadrigeminal body. The two systems, therefore, are not sharply separated from each other, and the chief distinction would appear to be that, whereas the main connexions of the cochlear nerve are ultimately established with the cerebral cortex and so enter the domain of consciousness, the main connexions of the vestibular nerve are with the spinal cord and cerebellum. Both systems can influence the motor nuclei of the brain-stem and the spinal cord, and they appear to share the subsidiary nuclei (nuclei of corpus trapezoideum and nucleus of lateral lemniscus).

Applied Anatomy.—The auditory nerve is frequently injured, together with the facial nerve, in fracture of the middle fossa of the skull implicating the internal auditory meatus. The nerve may be either torn across, producing permanent deafness, or bruised or pressed upon by extravasated blood or inflammatory exudation, when the deafness will in all probability be temporary. The nerve may also be injured by violent blows on the head without fracture of the skull, and deafness may arise from loud explosions, probably from some lesion of this nerve, which is more liable to be injured than the other cranial nerves on account of its structure. Tumours in the cerebellopontine angle involve the auditory and facial nerves, as they lie in relation to the flocculus (fig. 836) at the lower border of the pons.

The Glossopharyngeal Nerve (figs. 959, 960, 961)

The **glossopharyngeal nerve** contains motor and sensory fibres. It supplies motor fibres to the stylopharyngeus, secretomotor fibres to the parotid gland, and sensory fibres to the pharynx, the tonsil, and the posterior part of the tongue; it is also the nerve of taste for this part of the tongue. It is attached by three or four filaments to the upper part of the medulla oblongata, in the groove between the olive and the inferior cerebellar peduncle (restiform body).

The **sensory nucleus** is formed by the lower part of the *nucleus of the tractus solitarius*, which lies dorsilateral to the dorsal nucleus of the vagus below and ventrilateral to it at its upper end. It receives the central fibres of the unipolar cells of the superior and inferior (petrous) ganglia, which are situated on the trunk of the glossopharyngeal nerve and will presently be described. Some of the efferent fibres from this nucleus probably pass to the thalamus, where they are relayed to the hippocampal gyrus (sense of taste, posterior third of tongue).

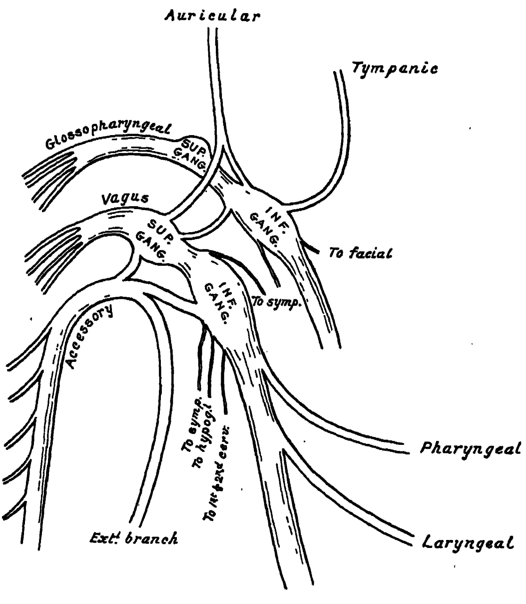
The **motor nucleus** is formed by the upper part of the *nucleus ambiguus* (p. 916), which lies deeply in the formatio reticularis of the medulla oblongata. It is connected with the pyramidal tract of the opposite side, and sends its efferent fibres to the stylopharyngeus muscle. This nucleus represents the branchial (special visceral) efferent column, but it lies more deeply in the substance of the medulla oblongata than might be expected (p. 916).

* See second footnote, p. 922.

In addition, fibres join the motor part of the glossopharyngeal nerve from a representative of the general visceral efferent column which is termed the **inferior salivary nucleus.** This nucleus lies in the reticular formation below the superior salivary nucleus, and sends its fibres *viâ* the tympanic branch to the lesser superficial petrosal nerve and the otic ganglion, whence they pass to the auriculotemporal nerve and so reach the parotid gland.

From the medulla oblongata the glossopharyngeal nerve passes forwards and laterally towards the triangular depression into which the aquæductus cochleæ opens, on the inferior surface of the petrous portion of the temporal bone. It lies at first under cover of the flocculus, and rests on the jugular tubercle of the occipital bone, which is sometimes grooved by it. It leaves the skull by bending sharply downwards through the central part of the jugular foramen, anterior and lateral to the vagus and accessory nerves, and in a separate sheath of dura mater (fig. 960). In its transit through the jugular foramen it is lodged in a deep groove leading from the triangular depression for the aquæductus cochleæ, and here it is separated by the inferior petrosal sinus from the vagus and accessory nerves. The deep groove is converted into a canal by a bridge which is usually composed of fibrous tissue, but consists of bone in about 25 per cent. of skulls.* After its exit from the skull it passes forwards between the internal jugular vein and internal carotid artery; it descends in front of the latter vessel, deep to the styloid process and the muscles connected with it, to reach the posterior border of the stylopharyngeus. It then curves forwards, lying upon the stylopharyngeus muscle, and either pierces the lower fibres of the superior constrictor of the pharynx or passes between the adjoining borders of the superior and middle constrictors (fig. 578) to be distributed to the tonsil, the mucous membrane of the pharynx and the posterior part of the tongue, and the mucous glands of the mouth.

FIG. 959.—A plan of the upper portions of the glossopharyngeal, vagus, and accessory nerves.



Two ganglia, named the superior and the inferior (petrous), are situated on that portion of the nerve which traverses the jugular foramen (fig. 959).

The **superior ganglion** is situated in the upper part of the groove in which the nerve is lodged during its passage through the jugular foramen. It is very small, gives off no branches, and is usually regarded as a detached portion of the inferior ganglion.

The **inferior ganglion** (petrous ganglion) is larger than the superior ganglion and is situated in a notch in the lower border of the petrous portion of the temporal bone (p. 272).

The glossopharyngeal nerve communicates with the sympathetic trunk, and with the vagus and facial nerves.

The inferior ganglion is connected by a filament with the superior cervical ganglion of the sympathetic. The branches to the vagus consist of two filaments which arise from the inferior ganglion; one joins the auricular branch, and the other the superior (jugular) ganglion, of the vagus. The branch to the facial arises from the trunk of the glossopharyngeal nerve below the inferior ganglion;

* E. Joyce Partridge, *Journal of Anatomy*, vol. lii.

it perforates the posterior belly of the digastric muscle and joins the facial nerve near the stylomastoid foramen.

The *branches of distribution* of the glossopharyngeal nerve are: tympanic, carotid, pharyngeal, muscular, tonsillar and lingual.

The **tympanic nerve** arises from the inferior ganglion of the glossopharyngeal nerve, and ascends to the tympanic cavity through the inferior tympanic canaliculus (p. 263). In the tympanic cavity it divides into branches which form the *tympanic plexus* and are contained in grooves upon the surface of the promontory. This plexus gives off: (1) the lesser superficial petrosal nerve; (2) a branch to join the greater superficial petrosal nerve; and (3) branches to the tympanic cavity, all of which are described with the anatomy of the middle ear (p. 1203).

The **carotid branches** descend along the trunk of the internal carotid artery as far as its origin, communicating with the pharyngeal branch of the vagus, and with branches of the sympathetic trunk; they are distributed to the wall of the carotid sinus (p. 700) and to the carotid body.

The **pharyngeal branches** are three or four filaments which unite, opposite the middle constrictor muscle of the pharynx, with the pharyngeal branch of the vagus nerve and the laryngopharyngeal branches of the sympathetic trunk to form the *pharyngeal plexus*; through this plexus the glossopharyngeal nerve supplies the mucous membrane of the pharynx with sensory branches.

The **muscular branch** supplies the stylopharyngeus muscle.

The **tonsillar branches** supply the tonsil, and form around it a plexus with branches of the lesser palatine nerves; from this plexus filaments are distributed to the soft palate and the region of the oropharyngeal isthmus.

The **lingual branches** are two in number: one supplies the vallate papillæ and the mucous membrane near the sulcus terminalis of the tongue; the other supplies the mucous membrane and follicular glands of the posterior one-third of the tongue, and communicates with the lingual nerve. It is the nerve of special sense (taste) and of general sensibility to the posterior one-third of the tongue.

The glossopharyngeal nerve is the nerve of the third branchial arch, or it would be more nearly correct to describe it as the post-trematic branch of that arch. The pretrematic branch of the second (hyoid) arch is probably the tympanic branch of the glossopharyngeal nerve, but that is uncertain. Like the trigeminal and the facial nerves, the glossopharyngeal corresponds to a dorsal nerve which has acquired special visceral efferent fibres.

The Vagus Nerve (figs. 959, 960, 961)

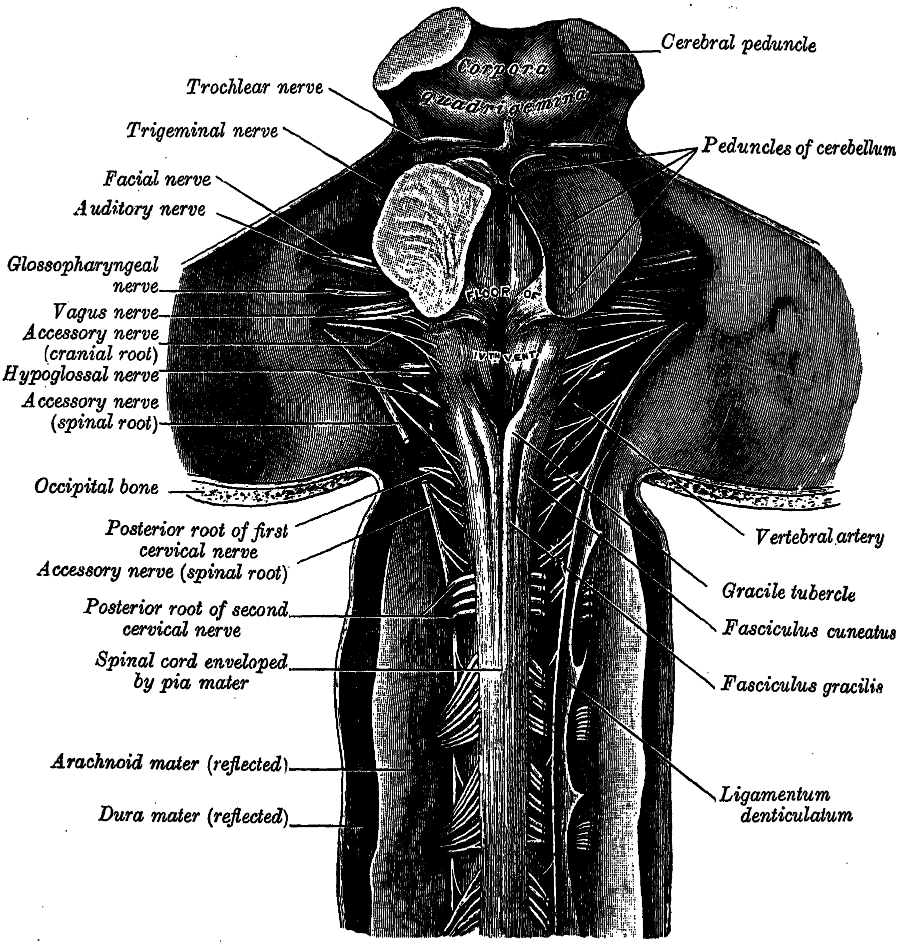
The **vagus nerve** is composed of motor and sensory fibres, and has a more extensive course and distribution than any of the other cranial nerves, since it passes through the neck and thorax to the abdomen. It is attached by eight or ten filaments to the medulla oblongata, below the glossopharyngeal nerve, in the groove between the olive and the inferior cerebellar peduncle (restiform body).

The fibres of the vagus nerve are connected to three nuclei in the medulla oblongata. (1) The **dorsal nucleus** of the vagus is a mixed nucleus and represents the fused general visceral efferent and general visceral afferent columns. It lies in the central grey matter of the lower, closed, part of the medulla oblongata, and extends upwards into the upper, open, part, where it is placed under the vagal triangle, separated from the hypoglossal nucleus by the nucleus intercalatus (p. 917). The *motor fibres* which arise from it are distributed to the involuntary muscle of the bronchi, heart, œsophagus, stomach and small intestines. The *sensory fibres* which terminate in the nucleus are derived from the larynx, pharynx, lungs, heart, œsophagus, stomach and small intestine. (2) Below the origin of the fibres which join the glossopharyngeal nerve, the **nucleus ambiguus** (pp. 916 and 1067) gives origin to those fibres of the vagus nerve which are distributed to the striped muscle of the pharynx and to the cricothyroid muscle. It represents the branchial (special visceral) efferent column, and its position in the deeper part of the medulla oblongata is attributable to neurobiotaxis (p. 911). It is uncertain whether the muscles of the soft palate are innervated by the vagal part of the nucleus ambiguus or by the

cerebral nucleus of the accessory nerve. (3) The lower end of the **nucleus of the tractus solitarius** (pp. 913 and 916) receives those fibres of the vagus which are distributed to the taste-buds of the epiglottis and the valleculæ. It represents the special visceral afferent column.

The filaments of the nerve unite, and form a flat cord which passes below the flocculus of the cerebellum to the jugular foramen, through which it leaves the cranium. In emerging through this opening, the vagus nerve is accompanied by and contained in the same sheath of dura and arachnoid mater as the

Fig. 960.—The upper part of the spinal cord, and the hind-brain and mid-brain. Exposed from behind.



accessory nerve, a fibrous septum separating them from the glossopharyngeal nerve, which lies in front (fig. 960). In this situation the vagus nerve presents a well-marked enlargement, named the *superior ganglion* (jugular ganglion). After its exit from the jugular foramen the vagus nerve enlarges into a second swelling, named the *inferior ganglion* (ganglion nodosum).

The **superior ganglion** (jugular ganglion) is of a greyish colour, spherical in form, about 4 mm. in diameter. It is joined by one or two delicate filaments with the cranial root of the accessory nerve; it is connected by a twig with the inferior ganglion of the glossopharyngeal nerve, and with the sympathetic trunk by a filament from the superior cervical ganglion; the auricular branch of the ganglion gives off an ascending twig which joins the facial nerve.

The **inferior ganglion** (ganglion nodosum) is cylindrical in form, of a reddish colour, and 2·5 cm. long. It is connected with the hypoglossal nerve, the

superior cervical ganglion of the sympathetic trunk, and the loop between the first and second cervical nerves. The cranial root of the accessory nerve passes over the ganglion, but is attached to it by fibrous tissue.

Beyond the inferior ganglion the cranial root of the accessory nerve blends with the vagus nerve ; its fibres are distributed principally to the pharyngeal and inferior laryngeal branches of the vagus nerve.

The vagus nerve passes vertically down the neck within the carotid sheath, lying between the internal jugular vein and internal carotid artery as far as the upper border of the thyroid cartilage, and then between the same vein and the common carotid artery to the root of the neck. The further course of the nerve differs on the two sides of the body.

On the *right side* the vagus nerve passes across the first part of the subclavian artery, between it and the right internal jugular vein. It enters the thorax and descends through the superior mediastinum, lying at first behind the right innominate vein, and then to the right of the trachea and posteromedial to the right innominate vein and the superior vena cava. The right pleura and lung are lateral to the nerve above, but are separated from it below by the azygos vein, which arches forward above the root of the right lung (fig. 785).

The nerve next passes behind the right bronchus to reach the posterior aspect of the root of the right lung, and there breaks up into posterior bronchial branches, which unite with filaments from the second, third and fourth thoracic sympathetic ganglia to form the *right posterior pulmonary plexus*. From the lower part of this plexus two or three branches descend on the back of the œsophagus, where, with a branch from the left vagus, they form the posterior part of the *œsophageal plexus* ; from this plexus the nerve is continued behind the œsophagus, and enters the abdomen through the œsophageal opening in the diaphragm. In the remainder of its course the nerve trunk contains fibres from both vagus nerves.

In the abdomen the posterior vagal trunk divides into a small gastric and a large cœliac branch. The gastric branch supplies the postero-inferior surface of the stomach with the exception of the pyloric canal. The cœliac branch ends chiefly in the cœliac ganglia, but sends twigs to the splenic, hepatic, renal, suprarenal and superior mesenteric plexuses.

On the *left side* the vagus nerve enters the thorax between the left common carotid and left subclavian arteries, and behind the left innominate vein. It descends through the superior mediastinum, crosses the aortic arch and passes behind the root of the left lung. Just above the aortic arch the nerve is crossed superficially by the left phrenic nerve, and on the arch by the left superior intercostal vein (fig. 998).

Behind the root of the left lung it divides into posterior bronchial branches, which unite with filaments of the second, third and fourth thoracic sympathetic ganglia and form the *left posterior pulmonary plexus*. From this plexus two branches descend on the front of the œsophagus where, with a twig from the right vagus, they form the anterior part of the *œsophageal plexus* ; from this plexus the nerve is continued in front of the œsophagus, and enters the abdomen through the œsophageal opening of the diaphragm. The nerve trunk now contains fibres from both vagus nerves.

In the abdomen the anterior vagal trunk nerve supplies twigs to the cardiac antrum, and then divides into right and left groups of branches. The fibres of the left group follow the lesser curvature of the stomach and supply the antero-superior surface of this viscus. The right group consists of three main branches. The first, which may be duplicated, runs between the layers of the lesser omentum towards the porta hepatis, and divides into (*a*) upper branches which enter the porta hepatis, and (*b*) lower branches which supply chiefly the pyloric canal, the pylorus, the first and second parts of the duodenum, and the head of the pancreas. The second branch is distributed to the antero-superior surface of the body of the stomach ; the third branch follows the lesser curvature of the stomach as far as the incisura angularis.*

* For further details, consult an article on "The Abdominal Distribution of the Vagus," by E. D'Arcy M'Crea, *Journal of Anatomy*, vol. lix. p. 18.

The *branches* of the vagus nerve are :

In the jugular fossa . .	Meningeal. Auricular.
In the neck	Pharyngeal. Branches to Carotid body. Superior laryngeal. Recurrent laryngeal (right). Cardiac.
In the thorax	Cardiac. Recurrent laryngeal (left). Pulmonary. Œsophageal.
In the abdomen	Gastric. Cœliac. Hepatic.

The **meningeal branch** springs from the jugular ganglion of the vagus nerve, and is distributed to the dura mater in the posterior fossa of the skull.

The **auricular branch** arises from the superior ganglion of the vagus nerve, and is joined soon after its origin by a filament from the inferior ganglion of the glossopharyngeal ; it passes behind the internal jugular vein, and enters the mastoid canaliculus on the lateral wall of the jugular fossa. Traversing the substance of the temporal bone, it crosses the canal for the facial nerve about 4 mm. above the stylomastoid foramen, and here it gives off an ascending branch which joins the facial nerve. It then passes through the tympano-mastoid fissure, and divides into two branches ; one joins the posterior auricular nerve, the other is distributed to the skin of part of the cranial surface of the auricle and to the posterior part of the external auditory meatus.

The **pharyngeal branch,** which is the principal motor nerve of the pharynx, arises from the upper part of the inferior ganglion of the vagus nerve, and consists principally of filaments from the cranial root of the accessory nerve. It passes between the external and internal carotid arteries to the upper border of the middle constrictor muscle of the pharynx, where it divides into numerous filaments which join with branches from the sympathetic trunk, the glossopharyngeal and external laryngeal nerves, to form the *pharyngeal plexus.* Through this plexus vagal fibres are distributed to the muscles of the pharynx, and the muscles of the soft palate, except the tensor palati. A minute filament joins the hypoglossal nerve as the latter winds round the occipital artery, and is termed the *ramus lingualis vagi.*

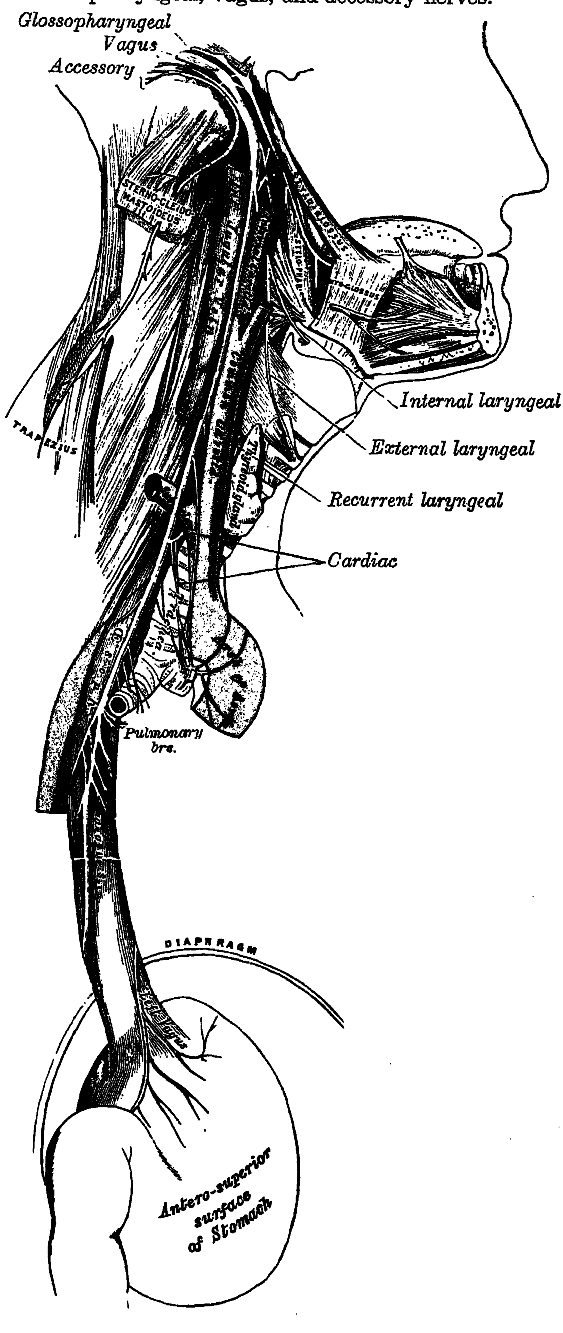
The *branches to the carotid body* are minute and variable in number. They may spring from the inferior ganglion or they may travel either in the pharyngeal branch or the superior laryngeal nerve.

The **superior laryngeal nerve,** which is larger than the preceding, arises from the middle of the inferior ganglion of the vagus nerve, and in its course receives a branch from the superior cervical ganglion of the sympathetic trunk. It descends, by the side of the pharynx, behind the internal carotid artery and divides into the internal and external laryngeal nerves.

The *internal laryngeal nerve* is sensory to the mucous membrane of the larynx as far down as the level of the vocal folds. It descends to the thyrohyoid membrane, pierces this membrane at a higher level than the superior laryngeal artery, and divides into an upper and a lower branch. The upper branch is directed horizontally, and supplies twigs to the mucous membrane of the pharynx, the epiglottis, the vallecula and the vestibule of the larynx. The lower branch descends in the medial wall of the piriform fossa, and gives branches to the aryepiglottic fold, and to the mucous membrane on the back of the arytenoid cartilage. It also supplies one or two branches to the arytænoideus muscle, and these branches unite with twigs from the recurrent laryngeal nerve to the same muscle ; the arytenoideus has there-

fore a double nerve-supply. The internal laryngeal nerve ends by piercing the inferior constrictor muscle of the pharynx, and joining with an ascending branch from the recurrent laryngeal nerve.*

FIG. 961.—The course and distribution of the glossopharyngeal, vagus, and accessory nerves.



The *external laryngeal nerve*, which is the smaller of the two, descends under cover of the sternothyroid muscle in company with the superior thyroid artery but on a deeper plane; it lies at first on the inferior constrictor muscle of the pharynx, and then, piercing that muscle, winds closely round the inferior thyroid tubercle and enters the cricothyroid muscle. It gives branches to the pharyngeal plexus and to the inferior constrictor; behind the common carotid artery it communicates with the superior cardiac nerve.

The **recurrent laryngeal nerve** (recurrent nerve) differs, as to its origin and course, on the two sides of the body. On the *right* side it arises from the vagus nerve in front of the first part of the subclavian artery; it winds from before backwards round that vessel, and ascends obliquely to the side of the trachea behind the common carotid artery. Near the lower pole of the lobe of the thyroid gland the nerve is always intimately related to the inferior thyroid artery; it may cross either in front of or behind the vessel, or may pass between its branches. On the *left* side, it arises from the vagus nerve on the left of the arch of the aorta, and winds below the arch immediately behind the attachment of the ligamentum arteriosum to the concavity of the arch, and then ascends to the side of the trachea. The nerve on each side ascends in the groove between the trachea and œsophagus, and is intimately related to the medial surface of the thyroid gland,† before it passes under the lower border of the inferior con-

* Consult an article on "The Nerves of the Human Larynx," by T. F. M. Dilworth, *Journal of Anatomy*, vol. lvi.

† F. G. Parsons (*Journal of Anatomy*, vol. liv.) pointed out that the right nerve may lie at some little distance from the groove between the trachea and the œsophagus.

strictor muscle and enters the larynx behind the articulation of the inferior cornu of the thyroid with the cricoid cartilage ; it gives branches to all the muscles of the larynx, excepting the cricothyroid. It communicates with the internal laryngeal nerve, and supplies sensory filaments to the mucous membrane of the larynx below the level of the vocal folds.

As the recurrent laryngeal nerve hooks round the subclavian artery, or the arch of the aorta, it gives several cardiac filaments to the deep part of the cardiac plexus. As it ascends in the neck it gives branches, more numerous on the left than on the right side, to the mucous membrane and muscular coat of the œsophagus ; branches to the mucous membrane and muscular fibres of the trachea ; and some filaments to the inferior constrictor muscle.

The **cardiac branches**, two or three in number, arise from the vagus nerve at the upper and lower parts of the neck. The *upper branches* are small, and join with the cardiac branches of the sympathetic trunk. They can be traced to the deep part of the cardiac plexus.

The *lower branches* arise at the root of the neck. That from the right vagus passes in front or by the side of the innominate artery, and proceeds to the deep part of the cardiac plexus ; that from the left runs down across the arch of the aorta, and joins the superficial part of the cardiac plexus.

Additional cardiac branches arise from the trunk of the right vagus nerve as it lies by the side of the trachea, and from both recurrent laryngeal nerves. They end in the deep part of the cardiac plexus. The cardiac plexus is described on p. 1149.

The **anterior pulmonary branches**, two or three in number and of small size, are distributed on the anterior surface of the root of the lung. They join with filaments from the sympathetic, and form the *anterior pulmonary plexus*.

The **posterior pulmonary branches**, more numerous and larger than the anterior, are distributed on the posterior surface of the root of the lung ; they are joined by filaments from the third and fourth (sometimes also from the first and second) thoracic ganglia of the sympathetic trunk, and form the *posterior pulmonary plexus*. Branches from this plexus accompany the ramifications of the bronchi and supply their constrictor muscles.

The **œsophageal branches** are given off both above and below the pulmonary branches ; the lower are more numerous and larger than the upper. They form, as already described (p. 1071), the *œsophageal plexus*. From this plexus filaments are distributed to the œsophagus and to the back of the pericardium.

The **gastric branches** are distributed to the stomach, the anterosuperior surface of which is mainly supplied by the left vagus, and the postero-inferior surface mainly by the right. The gastric branches sometimes form *anterior* and *posterior gastric plexuses*. " The pyloric canal, sphincter, and first stage of the duodenum receive their nerve-supply from above, receiving twigs from the vagal branches to the liver " (M'Crea).

The **cœliac branches** are derived from the right vagus : they join the cœliac ganglia.

The **hepatic branches** arise from both vagus nerves (p. 1071) : they join the hepatic plexus and through it are conveyed to the liver.

The vagus is a composite nerve and has been formed by the fusion of a number of dorsal nerves. It innervates the fourth, fifth and sixth branchial arches, but, in view of the presence of the large intestinal ramus in the vagus nerves of all fishes, it is impossible to speak with confidence as to the original number of its constituents.

It is interesting to observe that although the seventh and ninth cranial nerves have lost their somatic afferent constituent, it still persists in connexion with the tenth nerve, as its auricular branch. There is, however, some good grounds for supposing that its afferent fibres terminate in the nucleus of the spinal tract of the trigeminal nerve. However that may be, it is certain that irritation of the terminal twigs of the auricular branch in the external auditory meatus is capable of producing an efferent vagal response.

Applied Anatomy.—The trunk of the vagus is rarely injured, but the functions of the nerve may be interfered with by damage to its nucleus of origin in the medulla ; by thickening or growth from the meninges or bones, or aneurysm of the basilar artery, before its exit from the skull ; injuries such as gunshot or punctured wounds in the neck or

injuries during such operations as ligature of the carotid artery, removal of tuberculous glands or other deep-seated tumours. The vagus may also be compressed by aneurysms of the carotid artery, and its deep origin becomes affected in bulbar paralysis. The symptoms produced by paralysis of the nerve are palpitation, with increased frequency of the pulse, constant vomiting, slowing of the respiration, and a sensation of suffocation.

'Reflexes' in connexion with the branches of the vagus are not infrequent. The 'ear cough' is perhaps one of the commonest, where a plug of wax in the auditory meatus may, by irritating the filaments of the auricular nerve, be responsible for a persistent cough. Syringing the external auditory meatus frequently produces cough, and, in children, vomiting is not uncommon as the result of such a procedure; moreover, in people with weak hearts, syringing the ear has been responsible for a sudden fatal syncope, by reflex irritation of the cardiac branches. Another very common example is the persistent cough which is frequently due to enlarged bronchial glands in children, the irritation of which is referred to the superior laryngeal filaments.

The anatomy of the laryngeal nerves is of importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them reflex spasm of the glottis is the result. When its trunk is pressed upon by, for instance, a goitre or an aneurysm of the upper part of the carotid, there is a peculiar dry, brassy cough. When the nerve is paralysed, there is anæsthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, as the nerve also supplies the crico-thyroid muscle, the vocal folds cannot be made tense, and the voice is deep and hoarse. Paralysis may be the result of bulbar paralysis; may be a sequel to diphtheria, when both nerves are usually involved; or it may, though less commonly, be caused by the pressure of tumours or aneurysms, when the paralysis is generally unilateral. Irritation of the recurrent laryngeal nerves produces spasm of the muscles of the larynx. When both recurrent laryngeal nerves are paralysed, the vocal folds are motionless, in the so-called 'cadaveric position'—that is to say, in the position in which they are found in ordinary tranquil respiration; neither closed as in phonation, nor widely open as in deep inspiratory efforts. When one recurrent laryngeal nerve is paralysed, the vocal fold of the same side is motionless, while the opposite one crosses the median plane to accommodate itself to the affected one; hence phonation is possible, but the voice is altered and weak in timbre. Paralysis of the adductor muscles of the larynx on both sides is quite common, and is usually functional in nature. The voice is reduced to a whisper, but the power of coughing is preserved.

The Accessory Nerve (figs. 959, 960, 961)

The **accessory nerve** is formed by the union of a cranial and a spinal root. It represents the separated caudal rootlets of the vagus, but the separation is only partial, for its constituent parts are associated with each other only for a very short part of their course before the cranial part joins the vagus to be distributed through its branches. It is, however, both customary and convenient to describe it as a separate cranial nerve.

The **cranial root** is the smaller; its fibres arise from the cells of an elongated nucleus which is continuous above with the lower end of the **nucleus ambiguus** (p. 916) and emerge as four or five delicate rootlets from the side of the medulla oblongata, below the roots of the vagus. It runs laterally to the jugular foramen, where it interchanges fibres with the spinal root or becomes united to it for a short distance; here it is also connected by one or two filaments with the superior ganglion of the vagus. It passes through the jugular foramen, separates from the spinal portion, and is continued over the inferior ganglion of the vagus, to the surface of which it is adherent, and is distributed principally to the pharyngeal and recurrent laryngeal branches of the vagus. It is probably the source of the motor fibres which run in the pharyngeal branch of the vagus to supply the muscles of the soft palate, with the exception of the tensor palati. Some filaments from it are continued into the trunk of the vagus below the ganglion, to be distributed with the recurrent laryngeal nerve and probably also with the cardiac nerves.

The **spinal root** is firm in texture, and its fibres arise from an elongated nucleus of motor cells which is situated in the lateral part of the anterior grey column of the spinal cord, and extends downwards as low as the level of the fifth cervical nerve. Passing through the lateral white column of the spinal cord, they emerge on its surface and unite to form a trunk, which ascends between the ligamentum denticulatum and the posterior roots of the spinal nerves, and enters the skull through the foramen magnum, behind the vertebral

artery. It is then directed upwards and laterally to the jugular foramen, through which it passes in the same sheath of dura mater as the vagus nerve, but separated from that nerve by a fold of the arachnoid mater. In the jugular foramen, it receives one or two filaments from the cranial root, or else joins it for a short distance and then parts from it again. At its exit from the jugular foramen, it runs backwards over the internal jugular vein in about 66 per cent. of subjects, and deep to it in about 33 per cent. (Tandler). In this situation the accessory nerve crosses the transverse process of the atlas and is itself crossed by the occipital artery. The nerve then descends obliquely, passing deep to the styloid process, the stylohyoid muscle and the posterior belly of the digastric. Accompanied by the upper sternomastoid branch of the occipital artery, it reaches the upper part of the sternomastoid and pierces its deep surface (fig. 702), supplying it and joining with branches from the second cervical nerve. Emerging above the middle of the posterior border of the sternomastoid, the nerve crosses the posterior triangle of the neck lying on the levator scapulæ muscle, from which it is separated by the prevertebral layer of the deep cervical fascia and the fatty tissue which occupies the triangle. Here it is comparatively superficial, being related to the superficial cervical lymph glands and receiving communications from the second and third cervical nerves. Finally, about 5 cm. above the clavicle, the accessory nerve disappears under the anterior border of the trapezius and, together with branches from the third and fourth cervical nerves, forms a plexus on the deep surface of the muscle. From this plexus the trapezius receives its innervation.

The nucleus of the spinal root of the accessory nerve represents the branchial (special visceral) efferent column, and the muscles which it innervates must be regarded as greatly modified branchial muscles. It is not possible to identify the particular branchial arch which is concerned, but it must be caudal to the six arches which can be identified in the human embryo.

Applied Anatomy.—The functions of the accessory nerve may be interfered with either by central changes; or at its exit from the skull, by fractures running across the jugular foramen; or in the neck, by inflamed lymph glands, etc. The acute wry-neck in children is most commonly due to inflamed or suppurating glands, and rapidly subsides with appropriate treatment. Central irritation causes clonic spasm of the sternomastoid and trapezius muscles, or, as it is termed, spasmodic torticollis. In cases of this affection in which all previous palliative treatment has failed, and the spasms are so severe as to undermine the patient's health, division or excision of a portion of the accessory nerve has been resorted to.

In cases where extensive dissections are undertaken for enlarged glands in the neck, it is essential that this nerve should be sought at once and isolated from the mass of inflamed glands so as to maintain its continuity.

The Hypoglossal Nerve (figs. 960, 962, 963)

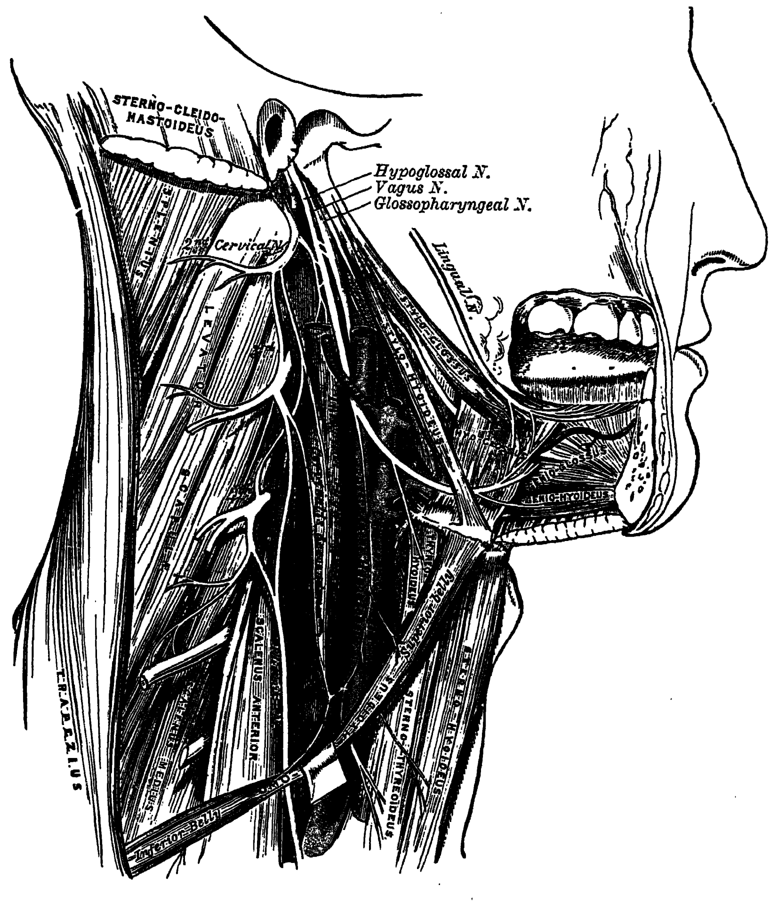
The **hypoglossal nerve** is the motor nerve of the tongue. It is in series with the third, fourth and sixth cranial nerves and the anterior nerve-roots of the spinal nerves, and represents the fused anterior roots of, probably, four precervical or spino-occipital nerves, the posterior roots of which have disappeared entirely.

The **nucleus** from which its fibres arise is in line with the base of the anterior grey column of the spinal cord. This nucleus is about 2 cm. long, and its upper part corresponds with the hypoglossal triangle of the floor of the fourth ventricle (p. 941). The lower part of the nucleus extends downwards into the closed part of the medulla oblongata, and there lies in relation to the ventrilateral aspect of the central canal (p. 910). It occupies the position of the somatic efferent column and therefore lies ventrimedial to the dorsal nucleus of the vagus (fig. 846). The fibres run forwards through the medulla oblongata, and emerge in the anterolateral sulcus between the pyramid and the olive (fig. 836).

The rootlets of the hypoglossal nerve run laterally behind the vertebral artery, and are collected into two bundles, which perforate the dura mater separately, opposite the anterior condylar (hypoglossal) canal in the occipital bone, and unite together after their passage through it; in some cases the canal is divided into two by a small bony spicule. The fact that each bundle acquires a separate sheath from the dura mater is confirmatory evidence of the

composite character of the nerve. On emerging from its canal the nerve lies on a deeper plane than the internal jugular vein, the internal carotid artery, the ninth, tenth and eleventh cranial nerves. It passes laterally, with a downward inclination, behind the internal carotid artery and the glossopharyngeal and vagus nerves to gain the interval between the artery and the internal jugular vein. In this part of its course it makes a half-spiral turn round the inferior ganglion of the vagus, to which it is united by a mass of connective tissue. It then descends almost vertically, lying between the vessels and in front of the vagus nerve, to a point corresponding with the angle of the mandible, and becomes superficial below the posterior belly of the digastric muscle. The nerve

FIG. 962.—The right hypoglossal nerve and cervical plexus.



then loops round the lower sternomastoid branch of the occipital artery (p. 710) and crosses the occipital and the external carotid arteries and the loop of the lingual artery (fig. 701), being itself crossed by the common facial vein. It inclines upwards as it runs forwards on the hyoglossus muscle, passing deep to the tendon of the digastric, the stylohyoid and the posterior border of the mylohyoid muscle. In the interval between the hyoglossus and mylohyoid muscles the nerve is related above to the deep part of the submandibular (submaxillary) gland, the submandibular duct and the lingual nerve. It passes next on to the lateral aspect of the genioglossus and is continued forwards in its substance as far as the tip of the tongue, distributing branches to its muscular substance. It communicates with the sympathetic trunk, and with the vagus, first and second cervical, and lingual nerves.

Opposite the atlas the nerve receives branches from the superior cervical ganglion of the sympathetic trunk, and at the same level is joined by a filament from the loop connecting the first and second cervical nerves.

The communications with the vagus nerve take place close to the skull, numerous filaments passing between the hypoglossal nerve and the inferior ganglion of the vagus nerve through the mass of connective tissue which unites them. As the nerve winds round the occipital artery it receives a filament from the pharyngeal plexus, which is termed the *ramus lingualis vagi*.

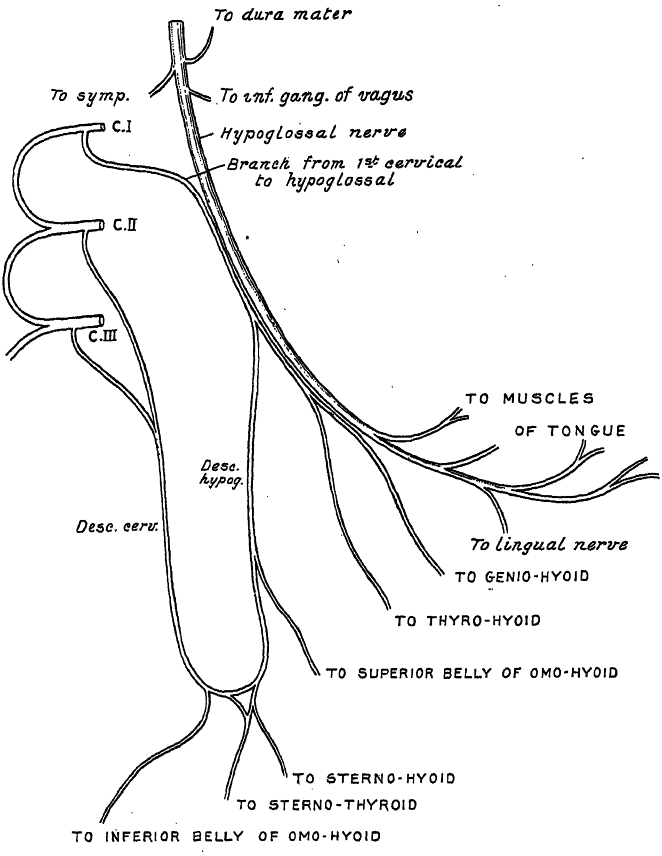
Near the anterior border of the hyoglossus it is united to the lingual nerve by numerous filaments which ascend upon the muscle.

The *branches of distribution* of the hypoglossal nerve are :

Meningeal.	Thyrohyoid.
Descending.	Muscular.

Of these branches the meningeal, descending, thyrohyoid, and that to the geniohyoid muscle, are probably derived mainly from the branch which passes

FIG. 963.—A plan of the hypoglossal nerve.



from the loop between the first and second cervical nerves to join the hypoglossal (fig. 963).

Meningeal branches.—As the hypoglossal nerve passes through the anterior condylar canal it supplies several filaments to the dura mater in the posterior fossa of the skull.

The **descending branch**, long and slender, leaves the hypoglossal nerve where the latter turns round the occipital artery, and descends in front of or within the sheath of the carotid vessels ; it gives a branch to the superior belly of the omohyoid muscle, and, just below the middle of the neck, joins the nervus descendens cervicalis from the second and third cervical nerves to form a loop, termed the *ansa hypoglossi*. From the convexity of this loop branches pass to supply the sternohyoid, the sternothyroid and the inferior belly of the

omohyoid muscle. According to Arnold, another filament descends in front of the vessels into the thorax, and joins the cardiac and phrenic nerves.

The **nerve to the thyrohyoid** arises from the hypoglossal nerve near the posterior border of the hyoglossus; it runs obliquely across the greater cornu of the hyoid bone, and supplies the thyrohyoid muscle.

The **muscular branches** are distributed to the styloglossus, hyoglossus, geniohyoid and genioglossus muscles. Numerous slender branches pass upwards into the substance of the tongue to supply its intrinsic muscles.

Applied Anatomy.—The hypoglossal nerve is an important guide in the operation of ligature of the lingual artery. It runs forwards on the hyoglossus just above the greater cornu of the hyoid bone, and forms the upper boundary of the triangular space in which the artery is to be sought by cutting through the fibres of the hyoglossus. In cases where the nerve is involved by gumma or new growth of the base of the skull, or where it has been injured on one side of the neck, or in some cases of bulbar paralysis, unilateral paralysis, together with hemiatrophy of the tongue, results; the tongue, when protruded, being directed to the paralysed side owing to the unopposed action of the genioglossus of the opposite side. On retraction, the wasted and paralysed side of the tongue rises up higher than the other. The larynx may deviate towards the sound side on swallowing, from the unilateral paralysis of the depressors of the hyoid bone. If the paralysis is bilateral, e.g. the result of a bullet wound of the infrahyoid region, the tongue lies motionless in the mouth, taste and tactile sensibility of the organ are perfect, articulation is slow and sticky; swallowing is very difficult, and the patient has to throw his head backwards and push the bolus of food back into the pharynx with his finger before he can swallow it.

THE MORPHOLOGICAL RELATIONSHIPS OF THE CRANIAL NERVES *

It is now possible to group the cranial nerves in a manner which conforms better with their phylogenetic history and with their individual components. At least three, probably four, and possibly five groups are necessary.

Group I includes the third, fourth, sixth and twelfth cranial nerves. These all arise from the cells of the somatic efferent column, and they are distributed to the musculature derived from the cranial myotomes. They correspond, therefore, to the anterior nerve-roots of the spinal nerves, and with the exception of the fourth, they emerge from the brain-stem, in line with them. The identification of the individual segments with which each nerve is associated is a matter of considerable difficulty and is not susceptible of proof in the present state of our knowledge, for the precise number of segments represented by the head is still uncertain (p. 103).

Group II includes the fifth, seventh, ninth, tenth and eleventh cranial nerves. These nerves were concerned with the innervation of the branchial arches, and they are placed in series with the posterior nerve-roots of the spinal nerves. They differ from the latter in possessing motor roots which are distributed to the musculature derived from the lateral mesodermic plates of the branchial region. Some of these cranial nerves (the fifth, tenth and eleventh), are compound nerves and have been formed by the fusion of two or more dorsal nerves (p. 1031). In the process cutaneous branches originally connected with the seventh, ninth and tenth nerves, have been taken over by the fifth, so that these nerves in man bear but little resemblance to their homologues in the lower forms of vertebrates and still less to the posterior nerve-roots of the spinal nerves.

On account of the complexity of their components, each nerve may possess more than one nucleus of origin and more than one nucleus of termination. It is noteworthy that the cells of the ganglion of the seventh, the inferior ganglion of the ninth and the inferior ganglion of the tenth nerve, though derived to a large extent from the neural crest, owe their origin in part to ectodermal epibranchial placodes which develop at the dorsal ends of the first three branchial clefts in close relation to the ganglia.

* For Analysis of the Cranial Nerves, see pp. 1080-81.

ANALYSIS OF THE CRANIAL NERVES.

NERVE	COMPONENTS	FUNCTION	CELLS OF ORIGIN	PRINCIPAL CENTRAL CONNEXIONS
Olfactory	Special somatic (? and visceral) afferent	Smell	In nasal mucous membrane	(*a*) Olfactory bulb (*b*) Olfactory pyramid and piriform area (*c*) Hippocampal formation
Optic	Special somatic afferent	Sight	Ganglionic layer of retina	(*a*) Lateral geniculate body and superior quadrigeminal body (*b*) Visuosensory cortex (*c*) Visuopsychic cortex
Oculomotor	Somatic efferent General visceral efferent	Movements of eyeball Contraction of pupil Accommodation	III. nucleus Edinger-Westphal nucleus	(*a*) Precentral gyrus (*b*) Middle frontal gyrus ?
	General somatic afferent	Proprioceptive (muscles of eyeball)	?	(*a*) Thalamus (*b*) Postcentral gyrus (*c*) ? Middle frontal gyrus
Trochlear	Somatic efferent	Movements of eyeball	IV. nucleus	(*a*) Precentral gyrus (*b*) Middle frontal gyrus
	General somatic afferent	Proprioceptive (Superior oblique muscle of eyeball)	?	(*a*) Thalamus (*b*) Postcentral gyrus
Trigeminal	Branchial (special visceral) efferent	Movements of mandible	Motor nucleus of V.	Precentral gyrus
	General somatic afferent	(i) General sensibility of skin, mucous membrane, etc. (*a*) Painful and thermal	Trigeminal ganglion	(*a*) Nucleus of tractus spinalis (*b*) Thalamus (*c*) Postcentral
		(*b*) Discriminative	Trigeminal ganglion	(*a*) Superior sensory nucleus of V. (*b*) Thalamus (*c*) Postcentral gyrus
		(ii) Proprioceptive (Muscles of mastication)	Mesencephalic nucleus of V.	(*a*) Thalamus (*b*) Postcentral gyrus
Abducent	Somatic efferent General somatic afferent	Lateral movement of eyeball Proprioceptive (lateral rectus muscle)	VI. nucleus ?	(*a*) Precentral gyrus (*b*) Middle frontal gyrus (*a*) Thalamus (*b*) Postcentral gyrus
Facial	Branchial (special visceral) efferent	Facial expression and elevation of hyoid bone	VII. nucleus	Precentral gyrus
	General visceral efferent	Secretomotor and vasodilator to submandibular and sublingual salivary glands	Superior salivary nucleus	?
	General somatic afferent	Proprioceptive (facial muscles, etc.)	Facial ganglion	(*a*) Thalamus (*b*) Postcentral gyrus
	Special visceral afferent	Taste; anterior two-thirds of tongue	Facial ganglion	(*a*) Nucleus of tractus solitarius (*b*) ? Thalamus (*c*) ? Hippocampal gyrus

Auditory				
Vestibular	General somatic afferent (modified)	Equilibration	Vestibular ganglion	(*a*) Vestibular nuclei (*b*) Cerebellum (*b*¹) Motor nuclei of other cranial nerves and anterior grey column of spinal cord
Cochlear	Special somatic afferent	Hearing	Spiral ganglion of cochlea	(*a*) Cochlear nuclei (*b*) Medial geniculate body and inferior quadrigeminal body (*c*) Auditosensory cortex (*d*) Auditopsychic cortex
Glossopharyngeal	Branchial (special visceral) efferent	Elevation of larynx in deglutition	Nucleus ambiguus	Precentral gyrus
	General visceral efferent	Secretomotor and vasodilator to parotid gland	Inferior salivary nucleus	?
	General visceral afferent	Mucous membrane of pharynx and posterior third of tongue	Inferior ganglion	?
	Special visceral afferent	Taste (posterior third of tongue)	Inferior ganglion	(*a*) Nucleus of tractus solitarius (*b*) ? Thalamus (*c*) ? Hippocampal gyrus
	General somatic afferent	Proprioceptive (stylopharyngeus muscle)	Superior ganglion	(*a*) Thalamus (*b*) Postcentral gyrus
Vagus and cranial root of Accessory	Branchial (special visceral) efferent	Movements of deglutition and phonation	Nucleus ambiguus	Precentral gyrus
	General visceral efferent	Movements of stomach and small intestine, see p. 1138	Dorsal nucleus of X.	?
	General visceral afferent	Mucous membrane of alimentary canal, etc.	Inferior ganglion	?
	Special visceral afferent	Taste (region of epiglottis)	Inferior ganglion	(*a*) Nucleus of tractus solitarius (*b*) ? Thalamus (*c*) ? Hippocampal gyrus
	General somatic afferent	General cutaneous sensibility of part of auricle and external auditory meatus	Superior ganglion	(*a*) ? Nucleus of spinal tract of V. (*b*) Thalamus (*c*) Postcentral gyrus
Accessory (spinal part)	Branchial (special visceral) efferent	Movements of head and shoulder (sternomastoid and trapezius)	Lateral part of anterior grey column of spinal cord (C. 1-C. 5)	Precentral gyrus
Hypoglossal	Somatic efferent	Movements of tongue	XII. nucleus	Precentral gyrus
	General somatic afferent	Proprioceptive (muscles of tongue)	?	(*a*) Thalamus (*b*) Postcentral gyrus

Although there are certain difficulties in the way, the homologies of the nerves in Groups I and II are generally accepted, but the allocation of the three remaining cranial nerves is entirely uncertain. On account of its mode of development, the optic nerve is usually regarded as having nothing in common with any of the other cranial nerves except its function as a special somatic afferent. The cells of the retina from which its fibres are derived really constitute an outlying part of the brain, although it may be urged that they are derivatives of the forerunners of the neural crest cells.

The olfactory and auditory nerves may be grouped together or separately, or the auditory nerve may be regarded as being homologous with a dorsal nerve. Both nerves arise, in part at least, from ectodermal cells outside the area of the neural tube and crest, but whereas the olfactory cells remain intercalated amongst the epithelial cells of the nasal mucous membrane, the auditory cells migrate a short distance away from the otic vesicle. It must be explained, however, that many authorities believe that the contribution made by the neural crest is responsible for the formation of the whole of the auditory ganglion, and on this account they prefer to regard the auditory as a modified dorsal nerve. In comparing the olfactory and auditory nerves it must be remembered that the olfactory nerves are restricted in all forms to the region of the head, whereas the auditory nerve in man is the sole survivor of a whole series of nerves of the organs of the lateral line, which in lower forms are distributed not only to the head but also to the whole length of the trunk. There is, therefore, considerable justification for the allocation of the olfactory and auditory nerves to separate groups.

THE SPINAL NERVES

The **spinal nerves** arise in series from the sides of the spinal cord and emerge through the intervertebral foramina. Each nerve is formed by the union of an anterior (motor) and a posterior (sensory) nerve-root, but these roots perforate the spinal dura mater independently before they unite (fig. 927), an indication that the two nerve-roots originally remain separate throughout their course (p. 1031). As they emerge from the intervertebral foramina the spinal nerves obviously possess a segmental character, but this feature is much less conspicuous in the connexions of the nerve-roots with the spinal cord. The anterior nerve-roots are the axons of the large motor cells of the anterior grey column, and are derivatives of the cells of the basal lamina of the neural tube. On the other hand, the posterior nerve-roots are the central branches of the axons of the unipolar cells of the spinal ganglia, and are therefore derivatives of the neural crest (p. 108).

The spinal nerves number thirty-one pairs, which are grouped as follows: cervical, 8; thoracic, 12; lumbar, 5; sacral, 5; coccygeal, 1.

The first cervical nerve emerges from the vertebral canal between the occipital bone and the atlas vertebra, and is therefore called the *suboccipital nerve*; the eighth issues between the seventh cervical and first thoracic vertebræ.

Nerve-roots.—Each nerve is attached to the spinal cord by an anterior and a posterior root (p. 903), the latter being characterised by the presence of a ganglion, which is termed the *spinal ganglion*.

The **anterior root** emerges from the anterior surface of the spinal cord as a number of rootlets or filaments, which coalesce to form two bundles near the intervertebral foramen.

The **posterior root** (except that of the first cervical nerve) is larger than the anterior; its rootlets are attached along the posterolateral furrow of the spinal cord and unite to form two bundles which join the spinal ganglion.

The **spinal ganglia** are collections of nerve-cells on the posterior roots of the spinal nerves. Each ganglion is oval in shape, reddish in colour, and its size bears a proportion to that of the nerve-root on which it is situated; it is bifid medially where it is joined by the two bundles of the posterior nerve-root. The ganglia are usually placed in the intervertebral foramina, immediately outside the points where the nerve-roots perforate the dura mater (fig. 965), but the

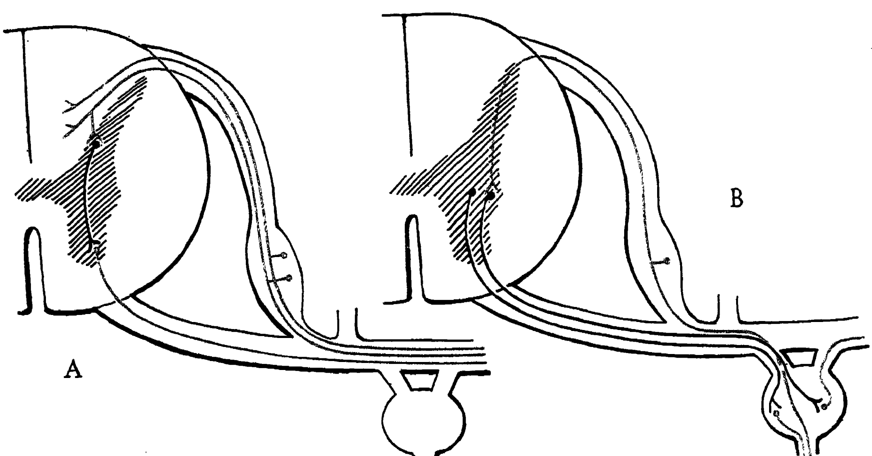
ganglia of the first and second cervical nerves lie on the vertebral arches of the atlas and axis, and those of the sacral nerves are inside the vertebral canal, and that of the coccygeal nerve is within the sheath of dura mater.

The ganglia of the first pair of cervical nerves may be absent, while small *aberrant ganglia* consisting of groups of nerve-cells are sometimes found on the posterior roots of the upper cervical nerves between the spinal ganglia and the spinal cord.

Each nerve-root receives a covering from the pia mater, and is loosely invested by the arachnoid mater, the latter being prolonged as far as the points where the roots pierce the dura mater. The two roots pierce the dura mater separately, each receiving a sheath from this membrane (fig. 927); where the roots join to form the spinal nerve this sheath is continuous with the epineurium of the nerve.

Size and direction.—The roots of the upper four *cervical* nerves are small; those of the lower four are large. The posterior roots of the cervical nerves bear a proportion to the anterior of three to one, which is greater than in the

FIG. 964.—Diagrams of the central connexions of the somatic fibres (A) and sympathetic fibres (B) of a typical spinal nerve. Afferent fibres, *blue*; connector neurons, *black*; and efferent fibres, *red*.



other regions; their individual filaments are also larger than those of the anterior roots. The posterior root of the first cervical is an exception to this, being smaller than the anterior root; in about eight per cent. of cases it is wanting. The roots of the first and second cervical nerves are short, and run nearly horizontally to their points of exit from the vertebral canal. From the third to the eighth cervical they are directed obliquely downwards, the obliquity and length of the roots successively increasing; the distance, however, between the level of attachment of any of these roots to the spinal cord and the points of exit of the corresponding nerves never exceeds the height of one vertebra.

The roots of the *thoracic* nerves, with the exception of the first, are of small size, and the posterior roots only slightly exceed the anterior in thickness. They increase successively in length, from above downwards, and, in the lower part of the thoracic region, descend in contact with the spinal cord for a distance equal to the height of at least two vertebræ before they emerge from the vertebral canal.

The roots of the lower *lumbar* and upper *sacral* nerves are the largest, and their individual filaments the most numerous of all the spinal nerves, while the roots of the *coccygeal* nerve are the smallest.

The roots of the lumbar, sacral, and coccygeal nerves run vertically downwards to their respective exits, and as the spinal cord ends near the lower border of the first lumbar vertebra it follows that the lengths of the successive

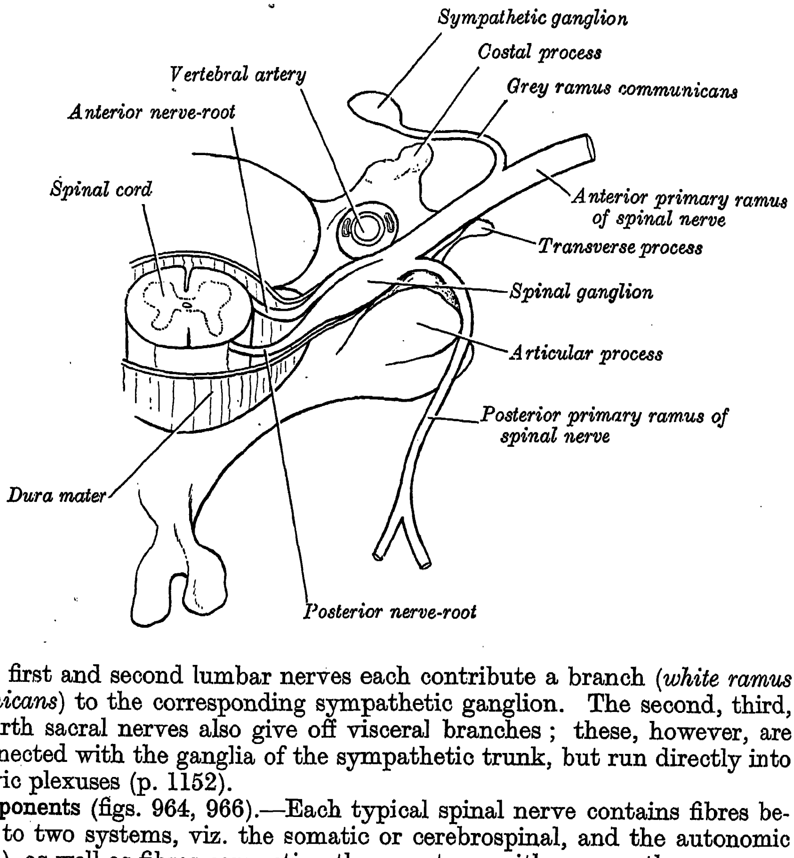
roots must rapidly increase. As already mentioned (p. 888), the term *cauda equina* is applied to this collection of nerve-roots.

From the description given it will be seen that the largest nerve-roots, and consequently the largest spinal nerves, are attached to the cervical and lumbar swellings of the spinal cord; these nerves are distributed to the upper and lower limbs.

Immediately beyond the spinal ganglion, the anterior and posterior nerve-roots unite to form the *spinal nerve*, which emerges through the intervertebral foramen.

Connexions with the sympathetic trunks.—After emerging from the intervertebral foramen each spinal nerve receives a branch (*grey ramus communicans*) from the corresponding ganglion of the sympathetic trunk, while the thoracic,

FIG. 965.—Scheme showing the relations of a cervical nerve and its ganglion to a cervical vertebra.



and the first and second lumbar nerves each contribute a branch (*white ramus communicans*) to the corresponding sympathetic ganglion. The second, third, and fourth sacral nerves also give off visceral branches; these, however, are not connected with the ganglia of the sympathetic trunk, but run directly into the pelvic plexuses (p. 1152).

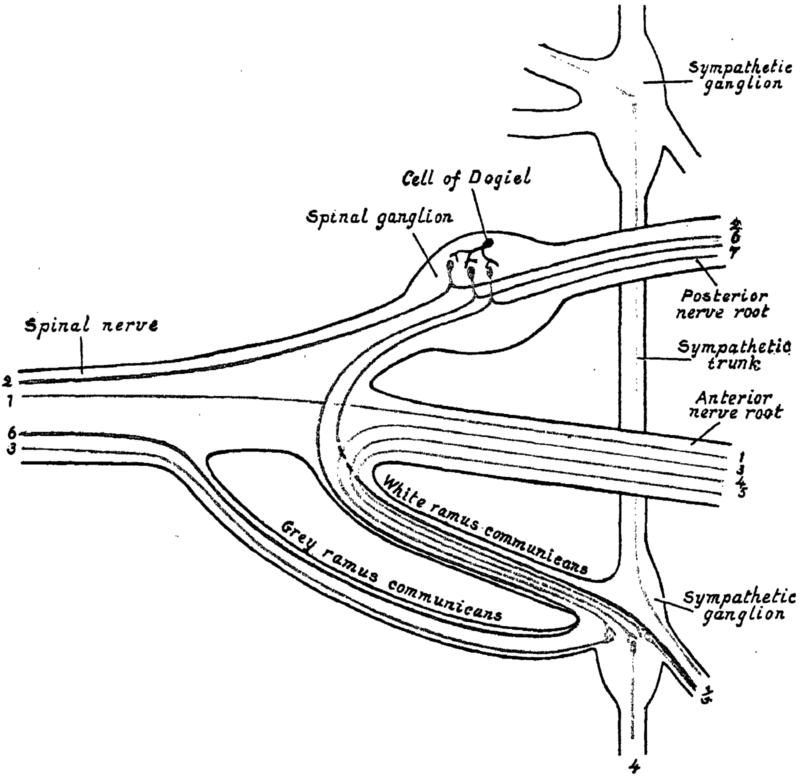
Components (figs. 964, 966).—Each typical spinal nerve contains fibres belonging to two systems, viz. the somatic or cerebrospinal, and the autonomic (fig. 966), as well as fibres connecting these systems with one another.

1. The *somatic efferent* fibres originate in the cells of the anterior grey column of the spinal cord, and run outwards through the anterior nerve-roots to the spinal nerve. They convey impulses to the voluntary muscles, and are continuous from their origin to their peripheral distribution. The *somatic afferent* fibres convey impressions inwards from the skin, etc., and originate in the unipolar nerve-cells of the spinal ganglia. The single processes of these cells divide into peripheral and central fibres, and the latter enter the spinal cord through the posterior nerve-roots.

2. The *autonomic* fibres are also efferent and afferent. The *efferent* fibres originate in the lateral column of the spinal cord, and are conveyed through the anterior nerve-roots and the white rami communicantes. Those issuing from the thoracic and lumbar regions of the spinal cord pass to the corresponding ganglia of the sympathetic trunk; here they may end by forming synapses around the cells of the ganglia, or they may run through one ganglion

to end in another on the sympathetic trunk, or in a more distally placed ganglion in one of the sympathetic plexuses. In all cases they end by forming synapses around other nerve-cells. From the cells of the ganglia of the sympathetic trunk other fibres (*postganglionic*) take origin ; some of these run through the grey rami communicantes to join the spinal nerves and are distributed to the blood-vessels, sweat glands, etc. ; others pass to the viscera. The fibres issuing from the sacral region of the spinal cord are *parasympathetic* ; they do not join the sympathetic ganglia but pass as the *pelvic splanchnic nerves* to the pelvic plexuses. The *afferent* fibres are derived from the cells of the spinal

FIG. 966.—A scheme showing the structure of a typical spinal nerve.



1. Somatic efferent. 2. Somatic afferent. 3, 4, 5. Autonomic efferent. 6, 7. Autonomic afferent.

ganglia. Their peripheral processes are carried through the white rami communicantes, and after passing without interruption through one or more sympathetic ganglia end in the tissues of the viscera. The central processes of the unipolar cells enter the spinal cord through the posterior nerve-roots and form synapses around either somatic or sympathetic efferent neurons, thus completing reflex arcs. Some authorities believe that the cells of Dogiel in the spinal ganglia (p. 1035) bring the autonomic afferent neurons into relationship with those of the somatic system, and so render possible the transference of an impulse from the former to the brain.

Rami or Divisions.—After emerging from the intervertebral foramen, each spinal nerve supplies a small *meningeal branch*, which re-enters the vertebral canal through the intervertebral foramen and is distributed to the vertebræ and their ligaments, and the blood-vessels of the spinal cord and its membranes. The spinal nerve then splits into a *posterior* and an *anterior primary ramus*, each receiving fibres from both nerve-roots.

THE POSTERIOR PRIMARY RAMI OF THE SPINAL NERVES

The **posterior primary rami** of the spinal nerves are as a rule smaller than the anterior. They are directed backwards, and, with the exceptions of those of the first cervical, the fourth and fifth sacral, and the coccygeal, divide into medial and lateral branches for the supply of the muscles and skin (fig. 967) of the posterior part of the trunk.

The Posterior Primary Rami of the Cervical Nerves

The posterior primary ramus of each cervical nerve, with the exception of the first, divides into a medial and a lateral branch. All these branches innervate muscles but, as a rule, only the medial branches of the second, third, fourth and, usually, the fifth, supply cutaneous areas. With the exception of the first and second, each posterior ramus passes backwards medial to the posterior intertransverse muscle and winds round the articular process to gain the interval between the semispinalis capitis and the semispinalis cervicis muscles.

The **posterior primary ramus of the first cervical or suboccipital nerve** (fig. 591) is larger than the anterior ramus, and emerges above the posterior arch of the atlas and below the vertebral artery. It enters the suboccipital triangle and supplies the muscles which bound this triangle, viz. the rectus capitis posterior major, and the superior and inferior oblique muscles ; it gives branches also to the rectus capitis posterior minor and the semispinalis capitis. A filament from the branch to the inferior oblique muscle joins the posterior primary ramus of the second cervical nerve (fig. 591).

The nerve occasionally gives off a cutaneous branch which accompanies the occipital artery to the scalp, and communicates with the greater and lesser occipital nerves.

The **posterior primary ramus of the second cervical nerve** is much larger than the anterior, and is the greatest of all the cervical posterior primary rami. It emerges between the posterior arch of the atlas and the lamina of the axis, below the inferior oblique muscle. It supplies a twig to this muscle, receives a communicating filament from the posterior primary ramus of the first cervical, and then divides into a large medial and a small lateral branch.

The *medial* branch, called from its size and distribution the *greater occipital nerve*, ascends obliquely between the inferior oblique and the semispinalis capitis, and pierces the latter muscle and the trapezius near their attachments to the occipital bone. It is then joined by a filament from the medial branch of the posterior primary ramus of the third cervical, and, ascending on the back of the head with the occipital artery, divides into branches which communicate with the lesser occipital nerve and supply the skin of the scalp as far forward as the vertex of the skull. It gives muscular branches to the semispinalis capitis, and occasionally a twig to the back of the auricle. The *lateral* branch supplies filaments to the splenius, longissimus capitis and semispinalis capitis, and is often joined by the corresponding branch of the third cervical.

The **posterior primary ramus of the third cervical nerve** is intermediate in size between those of the second and fourth. Its *medial* branch runs between the semispinalis capitis and semispinalis cervicis, and, piercing the splenius and trapezius, ends in the skin. While under the trapezius it gives a branch, called the *third occipital nerve*, which pierces the trapezius and ends in the skin of the lower part of the back of the head (fig. 967). It lies medial to the greater occipital nerve, and communicates with it. The *lateral* branch often joins that of the second cervical.

The posterior primary ramus of the suboccipital, and the medial branches of the posterior primary rami of the second and third cervical nerves are sometimes joined by communicating loops to form the *posterior cervical plexus* (Cruveilhier).

The posterior primary rami of the lower five cervical nerves divide into medial and lateral branches. The *medial* branches of the fourth and fifth run between

the semispinalis cervicis and semispinalis capitis, and, having reached the spines of the vertebræ, pierce the splenius and trapezius to end in the skin (fig. 967). Sometimes the medial branch of the fifth fails to reach the skin. The medial branches of the lowest three nerves are small, and end in the semispinalis cervicis, semispinalis capitis, multifidus and interspinales. The *lateral* branches of the lower five nerves supply the costocervicalis (iliocostalis cervicis), longissimus cervicis, and longissimus capitis.

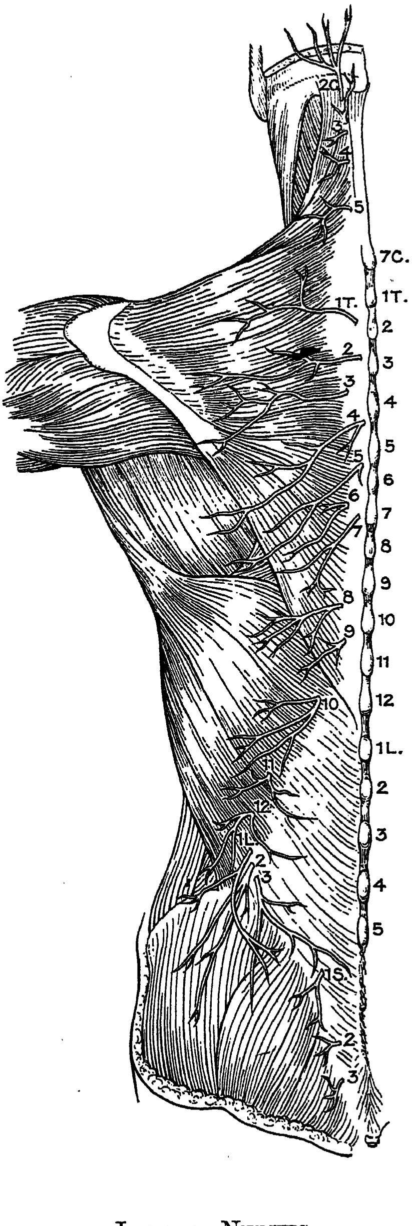


FIG. 967.—A diagram showing the distribution of the cutaneous branches of the posterior primary rami of the spinal nerves.

THE POSTERIOR PRIMARY RAMI OF THE THORACIC NERVES

The *medial* branches of the posterior primary rami of the upper six thoracic nerves run between the semispinalis thoracis and multifidus, which they supply; they then pierce the rhomboids and trapezius, and reach the skin by the sides of the spines (fig. 967). The medial branches of the lower six thoracic nerves are distributed chiefly to the multifidus and longissimus thoracis; occasionally they give filaments to the skin near the median plane.

The *lateral* branches increase in size from above downwards. They run through or deep to the longissimus thoracis to the interval between it and the iliocostocervicalis (iliocostalis), and supply these muscles; the lower five or six also give off cutaneous branches, which pierce the serratus posterior inferior and latissimus dorsi in a line with the angles or the ribs (fig. 967). The lateral branches of a variable number of the upper thoracic nerves also give filaments to the skin. The lateral branch of the twelfth thoracic, after sending a filament medially along the iliac crest, passes downwards to the skin of the anterior part of the buttock.

The medial cutaneous branches of the posterior primary rami of the thoracic nerves descend for some distance close to the spines before reaching the skin, while the lateral branches travel downwards for a considerable distance—it may be as much as the breadth of four ribs—before they become superficial; the branch from the twelfth thoracic, for instance, reaches the skin only a little way above the iliac crest.*

THE POSTERIOR PRIMARY RAMI OF THE LUMBAR NERVES

The *medial* branches of the posterior primary rami of the lumbar nerves run close to the articular processes of the vertebræ and end in the multifidus.

The *lateral* branches supply the sacrospinalis. The upper three give off cutaneous nerves which pierce the aponeurosis of the latissimus dorsi at the lateral border of the sacrospinalis and cross the posterior part of the iliac crest

* H. M. Johnston, *Journal of Anatomy and Physiology*, vol. xliii.

to reach the skin of the buttock (fig. 967), some of their twigs running as far as the level of the greater trochanter.

The Posterior Primary Rami of the Sacral Nerves

The **posterior primary rami of the sacral nerves** are small, and diminish in size from above downwards; they emerge, except the last, through the posterior sacral foramina. The *upper three* are covered at their points of exit by the multifidus, and divide into medial and lateral branches.

The *medial* branches are small, and end in the multifidus.

The *lateral* branches join with one another and with the lateral branches of the posterior primary rami of the last lumbar and fourth sacral to form loops on the dorsal surface of the sacrum. From these loops branches run to the dorsal surface of the sacrotuberous ligament and form a second series of loops under the gluteus maximus. From this second series of loops the *gluteal branches*, two or three in number, arise and at once pierce the gluteus maximus along a line drawn from the posterior superior iliac spine to the tip of the coccyx; they supply the skin over the posterior part of the buttock (fig. 967).

The posterior primary rami of the *lower two* sacral nerves are small and lie below the multifidus. They do not divide into medial and lateral branches, but unite with each other and with the posterior primary ramus of the coccygeal nerve to form loops on the back of the sacrum; filaments from these loops supply the skin over the coccyx.

The Posterior Primary Ramus of the Coccygeal Nerve

The **posterior primary ramus of the coccygeal nerve** does not divide into a medial and a lateral branch, but receives, as already stated, a communicating branch from the last sacral; it is distributed to the skin over the back of the coccyx.

THE ANTERIOR PRIMARY RAMI OF THE SPINAL NERVES

The **anterior primary rami of the spinal nerves** supply the limbs and the anterior and lateral aspects of the trunk; they are for the most part larger than the posterior primary rami. In the thoracic region they run independently of one another, but in the cervical, lumbar, and sacral regions they unite near their origins to form plexuses.

THE ANTERIOR PRIMARY RAMI OF THE CERVICAL NERVES

The **anterior primary rami of the cervical nerves**, with the exception of the first, appear between the corresponding anterior and posterior intertransverse muscles. The anterior primary rami of the *upper four* nerves unite to form the *cervical plexus*; those of the *lower four*, together with the greater part of the anterior primary ramus of the first thoracic nerve, join to form the *brachial plexus*.

Each nerve receives a grey ramus communicans, the upper four from the superior cervical ganglion, the fifth and sixth from the middle cervical ganglion, and the seventh and eighth from the inferior cervical ganglion, of the sympathetic trunk (see p. 1145).

The anterior primary ramus of the *first cervical* (*suboccipital*) *nerve* appears above the posterior arch of the atlas vertebra, and passes forwards round the lateral side of its lateral mass, medial to the vertebral artery. It supplies a branch to the rectus lateralis, and, emerging on the medial side of that muscle, descends in front of the transverse process of the atlas and behind the internal jugular vein, and joins with the ascending branch of the second nerve.

The anterior primary ramus of the *second cervical nerve* issues between the vertebral arches of the atlas and axis and runs forwards between the transverse processes of these two vertebræ; passing in front of the first posterior inter-transverse muscle and on the lateral side of the vertebral artery it emerges between the longus capitis and levator scapulæ muscles, but when the scalenus medius takes origin from the transverse process of the atlas, it intervenes between the nerve and the levator scapulæ. It divides into an ascending branch which joins with the first cervical nerve, and a descending branch which unites with the ascending branch of the third cervical nerve.

The anterior primary ramus of the *third cervical nerve* appears between the longus capitis and scalenus medius. The anterior primary rami of the remaining cervical nerves emerge between the scalenus anterior and scalenus medius.

The Cervical Plexus

The **cervical plexus** (fig. 968) is formed by the anterior primary rami of the upper four cervical nerves; each nerve, except the first, divides into an upper and a lower branch, and these unite to form three loops. The plexus is situated opposite the upper four cervical vertebræ, in front of the levator scapulæ and scalenus medius, and under cover of the internal jugular vein and the sternomastoid muscle.

Its branches are divided into two groups, *superficial* and *deep*, and are here given in tabular form; the figures following the names indicate the spinal nerves from which the different branches take origin:

Superficial			Lesser occipital	2 C.
			Great auricular	2, 3 C.
			Anterior cutaneous	2, 3 C.
			Supraclavicular	3, 4 C.
Deep	Medial	Communicating	With hypoglossal	1, 2 C.
			,, vagus	1, 2 C.
			,, sympathetic	1, 2, 3, 4 C.
		Muscular	Rectus capitis lateralis	1 C.
			Rectus capitis anterior	1, 2 C.
			Longus capitis	1, 2, 3 C.
			Longus cervicis	2, 3, 4 C.
			Descendens cervicalis	2, 3 C.
			Phrenic	3, 4, 5 C.
	Lateral	Communicating with accessory		2, 3, 4 C.
		Muscular	Sternomastoid	2 C.
			Trapezius	3, 4 C.
			Levator scapulæ	3, 4 C.
			Scalenus medius	3, 4 C.

The Superficial Branches of the Cervical Plexus (figs 968, 969)

The **lesser occipital nerve** (figs. 968, 969) arises from the second cervical nerve, sometimes also from the third; it hooks around the accessory nerve and ascends along the posterior border of the sternomastoid muscle. Near the cranium it perforates the deep fascia, and is continued upwards on the side of the head behind the auricle, supplying the skin and communicating with the great auricular and greater occipital nerves, and with the posterior auricular branch of the facial nerve. The lesser occipital nerve varies in size, and is sometimes duplicated.

It sends off an *auricular branch* which supplies the skin of the upper third of the cranial surface of the auricle, and communicates with the posterior branch of the great auricular nerve. The auricular branch is occasionally derived from the greater occipital nerve.

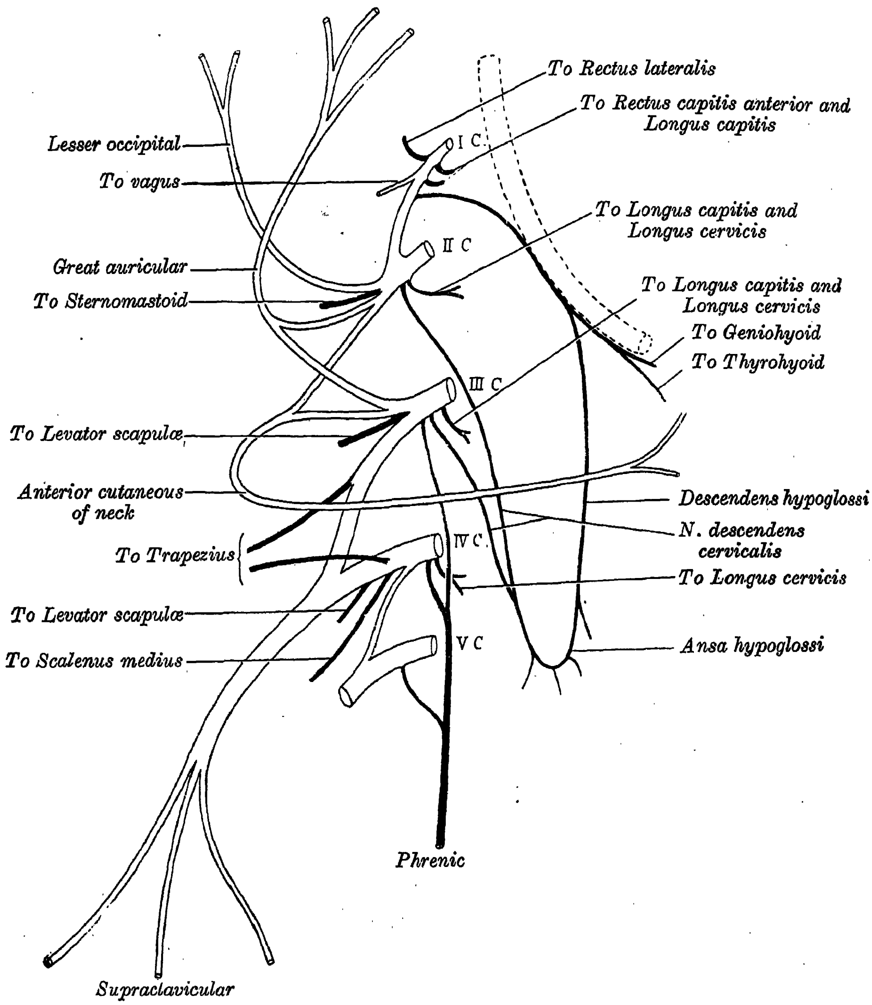
The **great auricular nerve** (figs. 968, 969) is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the sternomastoid muscle, and, after perforating the deep fascia, ascends upon that muscle beneath the platysma in company with the

external jugular vein. It passes on to the parotid gland, where it divides into an anterior and a posterior branch.

The *anterior branch* is distributed to the skin of the face over the parotid gland, and communicates in the substance of the gland with the facial nerve.

The *posterior branch* supplies the skin over the mastoid process and on the back of the auricle, except at its upper part; a filament pierces the auricle to reach its lateral surface, where it is distributed to the lobule and lower part

Fig. 968.—A plan of the cervical plexus.



of the concha. The posterior branch communicates with the lesser occipital nerve, the auricular branch of the vagus nerve, and the posterior auricular branch of the facial nerve.

The **anterior cutaneous nerve of the neck** (n. cutaneus colli) (figs. 968, 969) arises from the second and third cervical nerves, turns round the posterior border of the sternomastoid about its middle, and runs obliquely forwards, deep to the external jugular vein, to the anterior border of the muscle. It perforates the deep cervical fascia, and divides beneath the platysma into ascending and descending branches, which are distributed to the anterolateral parts of the neck.

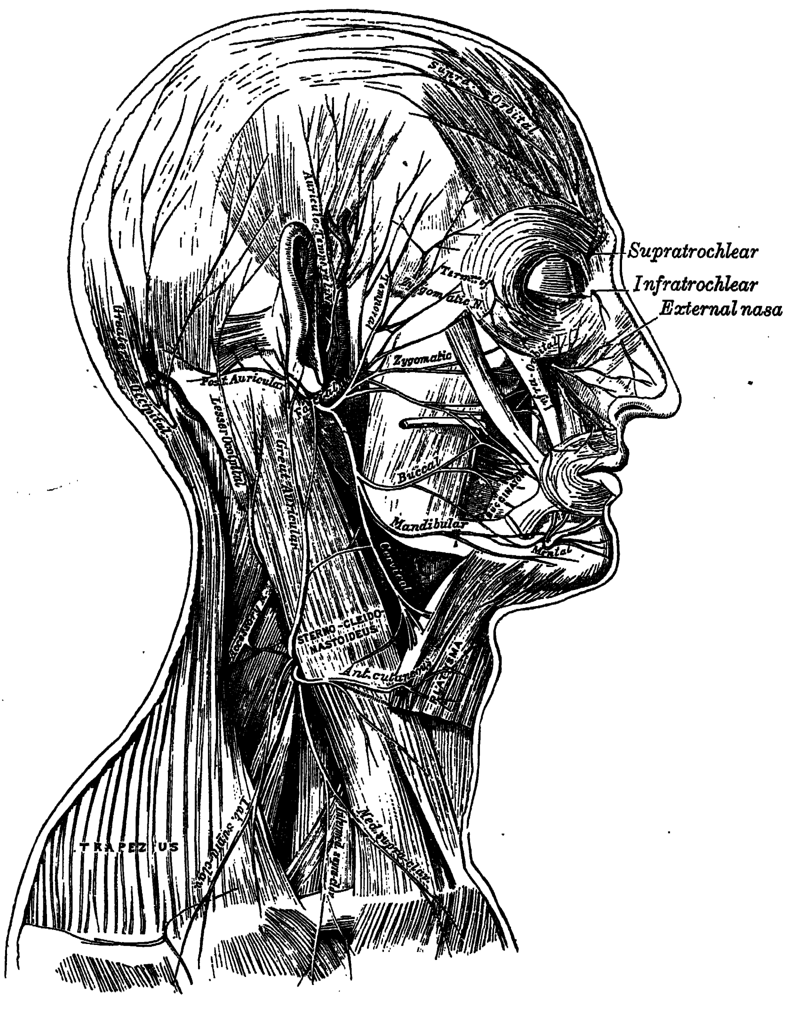
The *ascending branches* pass upwards to the submandibular region, and form a plexus with the cervical branch of the facial nerve, beneath the platysma;

others pierce that muscle, and are distributed to the skin of the upper and front parts of the neck.

The *descending branches* pierce the platysma, and are distributed to the skin of the side and front of the neck, as low as the sternum.

The **supraclavicular nerves** (figs. 968, 969) arise by a common trunk derived from the third and fourth cervical nerves. This trunk emerges from beneath the posterior border of the sternomastoid, descends under cover of the platysma and deep cervical fascia, and divides into medial, intermediate and lateral branches, which diverge from one another and pierce the deep fascia a little above the level of the clavicle.

FIG. 969.—The nerves of the right side of the scalp, face and side of neck.



The *medial supraclavicular nerves* cross obliquely over the external jugular vein and the clavicular and sternal heads of the sternomastoid, and supply the skin as far as the median plane. They furnish one or two filaments to the sternoclavicular joint.

The *intermediate supraclavicular nerves* cross the clavicle, and supply the skin over the pectoralis major and deltoid as low down as the level of the second rib. They communicate with the cutaneous branches of the upper intercostal nerves.

The *lateral supraclavicular nerves* pass obliquely across the outer surface of the trapezius and the acromion, and supply the skin of the upper and posterior parts of the shoulder.

Applied Anatomy.—Pains referred to the superficial terminal branches of the cervical plexus are not uncommon in caries of the cervical vertebræ, where pain may be felt radiating over the occipital bone, if the disease is situated high up in the vertebral column.

The Deep Branches of the Cervical Plexus. Medial Series

The **communicating branches** consist of several filaments which pass from the loop between the first and second cervical nerves to the vagus, hypoglossal and sympathetic. The branch to the hypoglossal ultimately leaves that nerve as a series of branches, viz. the meningeal, the nervus descendens hypoglossi, the nerve to the thyrohyoid and, possibly, the nerve to the geniohyoid (p. 1078). A communicating branch also passes from the fourth to the fifth cervical nerve, while each of the first four cervical nerves receives a grey ramus communicans from the superior cervical ganglion of the sympathetic trunk.

Muscular branches supply the rectus capitis lateralis, rectus capitis anterior, longus capitis and longus cervicis (longus colli) muscles.

The **nervus descendens cervicalis** (fig. 968) is formed usually by the union of two branches, one derived from the second cervical nerve and the other from the third. It passes downwards on the lateral side of the internal jugular vein, crosses in front of this vein a little below the middle of the neck, and forms a loop (*ansa hypoglossi*) with the descending branch of the hypoglossal nerve (p. 1078) in front of the sheath of the carotid vessels or in its substance. Not infrequently the nervus descendens cervicalis passes forwards between the internal jugular vein and the common carotid artery to reach the ansa hypoglossi (fig. 718).

The **phrenic nerve** contains motor and sensory fibres in the proportion of about two to one. It arises chiefly from the fourth cervical nerve, but receives a branch from the third and another from the fifth (fig. 968); the fibres from the fifth occasionally come through the nerve to the subclavius (p. 1096) and may descend for some distance into the thorax before joining the main trunk (accessory phrenic nerve). Formed at the lateral border of the scalenus anterior, and running obliquely across the front of that muscle, the phrenic nerve descends to the root of the neck, under cover of the sternomastoid, the inferior belly of the omohyoid, and the transverse cervical and suprascapular (transverse scapular) vessels (fig. 718). It next passes in front of the subclavian artery, between it and the subclavian vein, and, as it enters the thorax, crosses from the lateral to the medial side of the internal mammary artery (fig. 783). Within the thorax, it descends nearly vertically in front of the root of the lung, and then between the pericardium and the mediastinal pleura, to the diaphragm (fig. 785), where it divides into branches which pierce that muscle, and are distributed to its under-surface. In the thorax it is accompanied by the pericardiacophrenic branch of the internal mammary artery.

The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax.

The *right nerve* is situated more deeply, and is shorter and more vertical in direction than the left. It descends in front of the scalenus anterior which separates it from the second part of the subclavian artery. It lies lateral to the right innominate vein and superior vena cava, and is separated by the pericardium from the right atrium of the heart. Its terminal fibres pass through the vena caval opening in the diaphragm.

The *left nerve* is rather longer than the right, owing to the inclination of the heart to the left side, and to the diaphragm being lower on this than on the right side. At the root of the neck it crosses in front of the first part of the subclavian artery, and is itself crossed by the thoracic duct. In the superior mediastinum it lies between the left common carotid and left subclavian arteries, and crosses superficial to the vagus nerve just above the level of the arch of the aorta. It next crosses the arch of the aorta and passes in front of the root of the left lung to reach the left side of the pericardium, by which it is separated from the left ventricle of the heart.

Each nerve supplies branches to the pericardium and pleura, and at the root of the neck is joined by a filament from the sympathetic, and, occasionally, by one from the ansa hypoglossi.

From the *right nerve*, one or two filaments pass with phrenic branches of the cœliac plexus to join in a small *phrenic ganglion*; and branches from this ganglion are distributed to the falciform and coronary ligaments of the liver, the suprarenal gland and inferior vena cava. From the *left nerve*, filaments pass to join the phrenic branches of the cœliac plexus, but without any ganglionic enlargement; and a twig is distributed to the left suprarenal gland.

Applied Anatomy.—In addition to its supply from the phrenics, the diaphragm receives innervation from the lower seven intercostal nerves at its periphery. This double sensory innervation explains the varied distribution of the referred pains that may be felt in different cases of infection or inflammation of the diaphragm, such as may occur in pleurisy or pneumonia affecting its upper surface, on the one hand, or in peritonitis attacking its lower surface on the other. For example, if it is the more central part of the diaphragm that becomes inflamed in a case of acute peritonitis, the patient may complain of pain and tenderness in the area of distribution of the cutaneous branches of the fourth and fifth cervical nerves, with the result that disease of the shoulder-joint or supraclavicular region is erroneously suspected, and the peritonitis is missed. On the other hand, if the periphery of the diaphragm chances to become infected in a patient with acute pleurisy or pneumonia, he may complain of acute pain and tenderness in the area of distribution of the cutaneous branches of the lower intercostal nerves, and may also exhibit rigidity of the underlying abdominal muscles, with the result that an acute intra-abdominal infection is erroneously diagnosed and a laparotomy is performed for the relief of a supposed appendicitis, cholecystitis or localised peritonitis.

The Deep Branches of the Cervical Plexus. Lateral Series

Communicating branches.—The lateral series of deep branches of the cervical plexus communicates with the accessory nerve, in the substance of the sternomastoid, in the posterior triangle and under cover of the trapezius.

Muscular branches are distributed to the sternomastoid, trapezius, levator scapulæ and scalenus medius muscles.

The branch for the sternomastoid is derived from the second cervical nerve; the trapezius and levator scapulæ receive branches from the third and fourth cervical nerves, those to the trapezius crossing the posterior triangle obliquely at a lower level than the accessory nerve. The scalenus medius receives twigs either from the third or fourth cervical nerves, or occasionally from both.

The Brachial Plexus

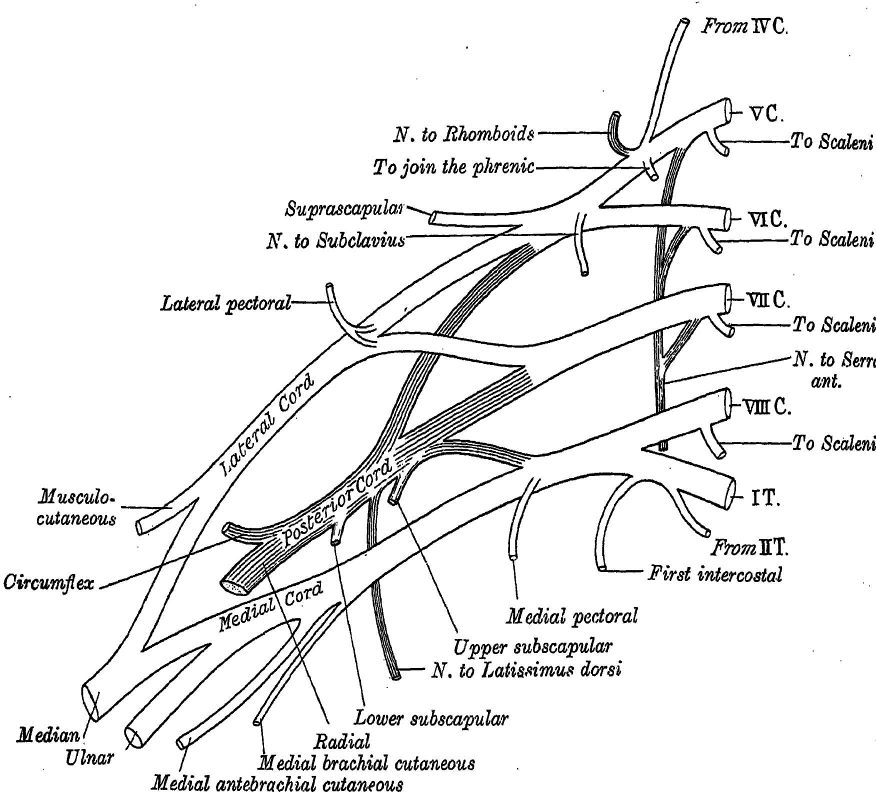
The **brachial plexus** (fig. 970) is formed by the union of the anterior primary rami of the lower four cervical nerves and the greater part of the anterior primary ramus of the first thoracic nerve; the fourth cervical nerve usually gives a branch to the fifth cervical, and the first thoracic nerve frequently receives one from the second thoracic. These nerves constitute the *roots* of the plexus, which extends from the lower part of the side of the neck to the axilla. The roots are nearly equal in size, but their mode of communication is subject to some variation. The following is, however, the most constant arrangement. The fifth and sixth cervical nerves unite at the lateral border of the scalenus medius to form the *upper trunk* of the plexus. The eighth cervical and first thoracic nerves unite behind the scalenus anterior to form the *lower trunk* of the plexus, while the seventh cervical nerve itself constitutes the *middle trunk*. These three trunks run downwards and laterally and as—sometimes before—they pass behind the clavicle, each splits into an *anterior* and a *posterior* division.* The anterior divisions of the upper and middle trunks unite to form a cord, which is situated on the lateral side of the axillary artery, and is called the *lateral cord* of the plexus. The anterior division of the lower trunk passes down at first behind and then on the medial side of the axillary artery, and forms the *medial cord* of the brachial plexus; this cord frequently receives fibres from the seventh cervical nerve. The posterior divisions of all three

* The posterior division of the lower trunk is very much smaller than the others, and is frequently derived from the eighth cervical nerve before the trunk is formed.

trunks unite to form the *posterior cord* of the plexus, which is situated at first above and then behind the axillary artery.

Relations.—*In the neck*, the brachial plexus lies in the posterior triangle in the angle between the clavicle and the lower part of the posterior border of the sternomastoid, being covered by the skin, platysma and deep fascia; it is crossed by the supraclavicular nerves, the nerve to the subclavius, the inferior belly of the omohyoid, the external jugular vein and the transverse cervical artery (fig. 971). It emerges between the scalenus anterior and scalenus medius; its upper part lies above the third part of the subclavian artery, while the lower trunk is placed behind the artery; the plexus next passes behind the clavicle, the subclavius and the suprascapular (transverse scapular) vessels, and lies

FIG. 970.—A plan of the brachial plexus.



upon the first digitation of the serratus anterior and the subscapularis. *In the axilla* the lateral and posterior cords of the plexus are on the lateral side of the first part of the axillary artery, and the medial cord behind it. The cords surround the second part of the axillary artery on three sides, the medial cord lying on the medial side, the posterior cord behind, and the lateral cord on the lateral side of the artery. In the lower part of the axilla the cords split into the nerves for the upper limb.

Close to their exit from the intervertebral foramina the fifth and sixth cervical nerves receive grey rami communicantes from the middle cervical ganglion, and the seventh and eighth cervical similar rami from the inferior cervical ganglion, of the sympathetic trunk (p. 1145). The first thoracic nerve receives a grey ramus from, and contributes a white ramus to, the first thoracic ganglion of the sympathetic trunk.

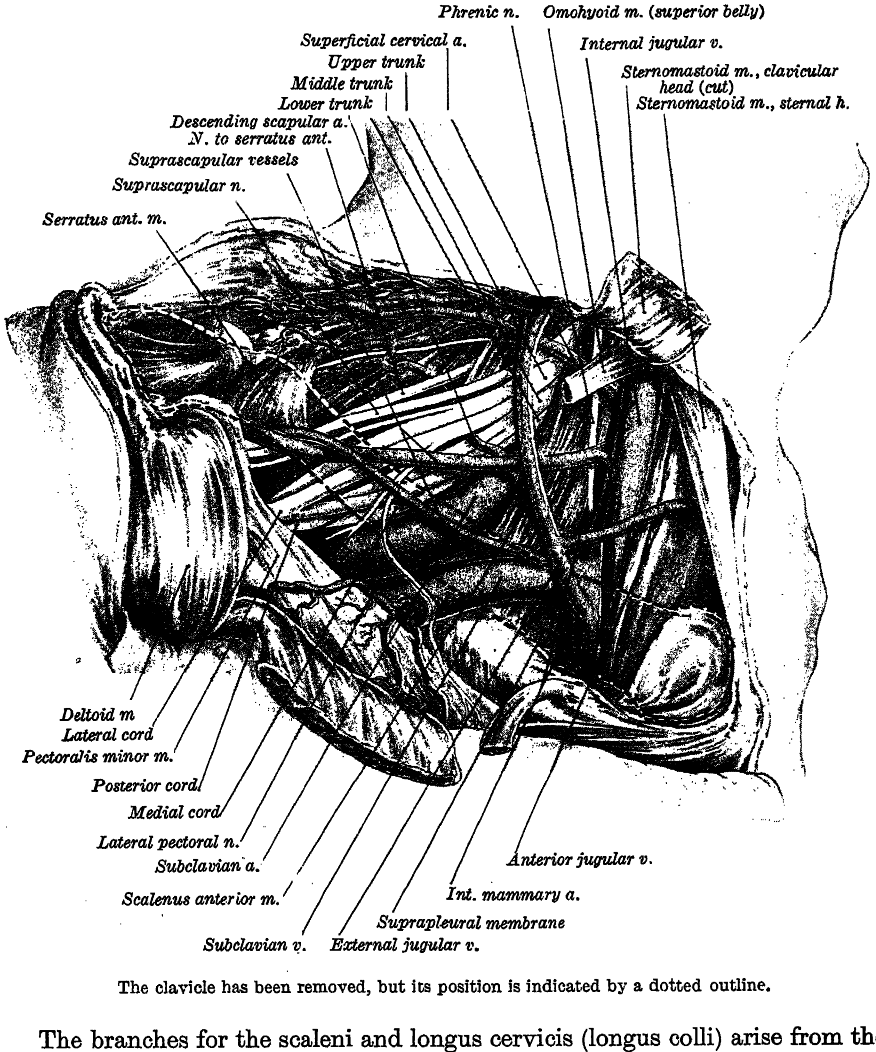
The branches of the brachial plexus.—The branches of the brachial plexus are usually subdivided into two groups, viz. those arising above the clavicle (*supraclavicular*) and those below that bone (*infraclavicular*).

The Supraclavicular Branches

The supraclavicular branches may be grouped as follows : (*a*) those arising from the roots, and (*b*) those arising from the trunks of the plexus.

From the roots of the plexus.	1. To scaleni and longus cervicis	5, 6, 7, 8 C.
	2. To join phrenic nerve . .	5 C.
	3. Nerve to rhomboids . .	5 C.
	4. Nerve to serratus anterior .	5, 6, 7 C.
From the trunks of the plexus.	1. Nerve to subclavius . .	5, 6 C.
	2. Suprascapular nerve . .	5, 6 C.

Fig. 971.—A dissection of the brachial plexus of the right side, viewed from the anterolateral aspect.



The clavicle has been removed, but its position is indicated by a dotted outline.

The branches for the scaleni and longus cervicis (longus colli) arise from the lower four cervical nerves close to their points of exit from the intervertebral foramina.

On the scalenus anterior the phrenic nerve is joined by a branch from the fifth cervical nerve.

The **nerve to the rhomboids** arises from the fifth cervical nerve, pierces the scalenus medius, passes on to the deep surface of the levator scapulæ, to which it occasionally gives a twig, and runs in company with the deep branch of the

transverse cervical artery on the anterior surfaces of the rhomboids; it ends by supplying these muscles.

The **nerve to the serratus anterior** (fig. 971) usually arises by three roots from the fifth, sixth, and seventh cervical nerves, but the root from the seventh nerve may be absent. The roots from the fifth and sixth nerves pierce the scalenus medius, while that from the seventh passes laterally in front of the muscle. The nerve descends behind the brachial plexus and the first part of the axillary vessels, resting on the outer surface of the serratus anterior. It is continued down to the lower border of that muscle, supplying, in its course, filaments to each of its digitations.

The **nerve to the subclavius** is a small nerve which arises from the point of junction of the fifth and sixth cervical nerves; it descends in front of the plexus and the third part of the subclavian artery, and is usually connected by a filament with the phrenic nerve. It then passes behind the subclavian vein and reaches the subclavius muscle, which it supplies.

The **suprascapular nerve** (fig. 977) is a large nerve which arises from the upper trunk of the brachial plexus. It runs laterally deep to the trapezius and the omohyoid, and enters the supraspinous fossa through the suprascapular notch, passing below the suprascapular ligament; it then runs deep to the supraspinatus, and curves round the lateral border of the spine of the scapula in company with the suprascapular (transverse scapular) artery to gain the infraspinous fossa. In the supraspinous fossa it gives two branches to the supraspinatus muscle, and articular filaments to the shoulder-joint and acromioclavicular joint; and in the infraspinous fossa it gives two branches to the infraspinatus muscle, besides some filaments to the shoulder-joint and scapula.

The Infraclavicular Branches

The infraclavicular branches are derived from the three cords of the brachial plexus, but their fibres may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

Lateral cord	Lateral pectoral	5, 6, 7 C.
	Musculocutaneous	5, 6, 7 C.
	Lateral root of median	6, 7 C.
Medial cord	Medial pectoral	8 C., 1 T.
	Medial cutaneous of forearm	
	Medial cutaneous of arm	
	Medial root of median	
	Ulnar *	(7), 8 C., 1 T.
Posterior cord	Upper subscapular	5, 6 C.
	Lower subscapular	5, 6 C.
	Circumflex	5, 6 C.
	Nerve to latissimus dorsi	6, 7, 8 C.
	Radial	5, 6, 7, 8 C., 1 T.

The **pectoral nerves** (fig. 976) supply the pectoralis major and pectoralis minor.

The *lateral pectoral nerve* (lateral anterior thoracic nerve), the larger of the two, may arise by two roots from the anterior divisions of the upper and middle trunks, or by a single root from the point where these divisions unite to form the lateral cord of the plexus; it receives its fibres from the fifth, sixth, and seventh cervical nerves. It crosses the axillary artery and vein, pierces the clavipectoral fascia, and is distributed to the deep surface of the pectoralis major. It sends a filament to join the medial pectoral nerve and form with it a loop in front of the first part of the axillary artery; through this loop the lateral pectoral nerve distributes some fibres to the pectoralis minor.

The *medial pectoral nerve* (medial anterior thoracic nerve) receives its fibres from the eighth cervical and first thoracic nerves, and arises from the medial cord of the plexus while that cord is still posterior to the axillary artery. It

* See footnote on p. 1101.

curves forwards between the axillary artery and vein, and unites in front of the artery with a filament from the lateral pectoral nerve. It then enters the deep surface of the pectoralis minor and supplies that muscle. Two or three branches pierce the pectoralis minor, and others may pass round its inferior border, to end in the pectoralis major.

The **subscapular nerves**, two in number, spring from the posterior cord of the plexus, and through it from the fifth and sixth cervical nerves.

The *upper subscapular nerve*, the smaller, enters the upper part of the subscapularis, and is frequently represented by two branches.

The *lower subscapular nerve* supplies the lower part of the subscapularis, and ends in the teres major; the latter muscle is sometimes supplied by a separate branch.

The **nerve to latissimus dorsi** (thoracodorsal nerve), a branch of the posterior cord of the plexus, derives its fibres from the sixth, seventh and eighth cervical nerves; it accompanies the subscapular artery along the posterior wall of the axilla and supplies the latissimus dorsi, in which it may be traced as far as the lower border of the muscle.

The **circumflex nerve** (axillary nerve) (fig. 977) arises from the posterior cord of the brachial plexus, its fibres being derived from the fifth and sixth cervical nerves. It lies at first on the lateral side of the radial nerve and is placed behind the axillary artery, and in front of the subscapularis. At the lower border of that muscle it winds backwards in close relation to the lowest part of the articular capsule of the shoulder-joint, and, in company with the posterior circumflex humeral vessels, passes through a quadrangular space bounded above by the subscapularis, in front, and the teres minor, behind, below by the teres major, medially by the long head of the triceps and laterally by the surgical neck of the humerus. The nerve ends by dividing into an anterior and a posterior branch.

The *anterior branch*, accompanied by the posterior circumflex humeral vessels, winds round the surgical neck of the humerus, deep to the deltoid, as far as the anterior border of the muscle, supplying it, and giving a few small cutaneous branches which pierce the muscle and ramify in the skin covering its lower part.

The *posterior branch* supplies the teres minor and the posterior part of the deltoid; upon the branch to the teres minor an oval enlargement (pseudoganglion) usually exists. The posterior branch then pierces the deep fascia and is continued as the *upper lateral cutaneous nerve of the arm*, which sweeps round the posterior border of the deltoid and supplies the skin over the lower two-thirds of the posterior part of this muscle, and the skin covering the long head of the triceps (figs. 972, 973).

The trunk of the circumflex nerve gives an articular filament which enters the shoulder-joint below the subscapularis.

The **musculocutaneous nerve** (fig. 976) arises from the lateral cord of the brachial plexus, opposite the lower border of the pectoralis minor, its fibres being derived from the fifth, sixth, and seventh cervical nerves. It pierces the coracobrachialis and runs downwards and laterally between the biceps and the brachialis to reach the lateral side of the arm; a little below the elbow it pierces the deep fascia on the lateral side of the tendon of the biceps and is continued into the forearm as the *lateral antebrachial cutaneous nerve*. In its course through the arm it supplies the coracobrachialis, both heads of the biceps and the greater part of the brachialis. The branch to the coracobrachialis leaves the musculocutaneous nerve before that nerve enters the muscle; it receives its fibres from the seventh cervical nerve, and in some instances arises directly from the lateral cord of the brachial plexus. The branches to the biceps and brachialis leave the musculocutaneous nerve after it has pierced the coracobrachialis; that supplying the brachialis gives a filament to the elbow-joint. The nerve also sends a small branch to the humerus; this branch enters the bone with the nutrient artery.

The *lateral cutaneous nerve of the forearm* (fig. 972) passes deep to the cephalic vein, and descends along the radial border of the forearm to the wrist. It supplies the skin over the lateral half of the anterior surface of the forearm and distributes branches which turn round the radial border of the forearm to

communicate with the posterior cutaneous nerve of the forearm and the terminal branch of the radial nerve. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the dorsal surface of the carpus. The nerve then passes downwards

Fig. 972.—The cutaneous nerves of the right upper limb. Anterior surface.

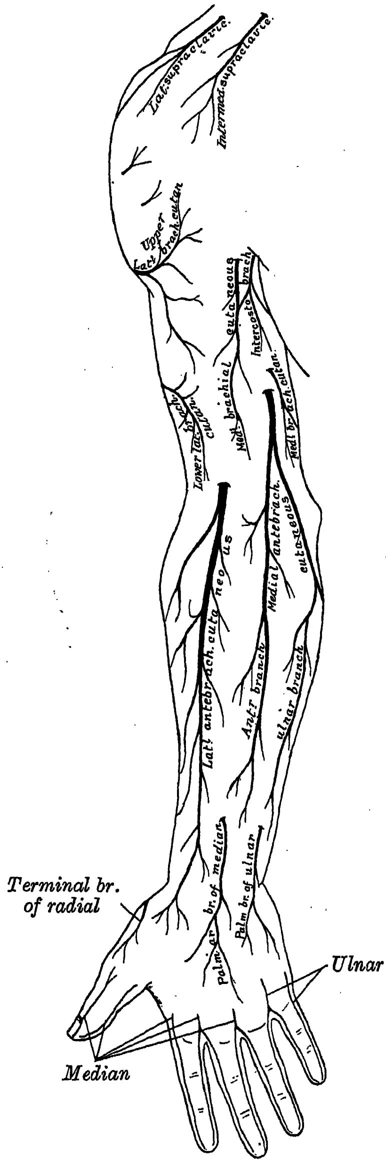
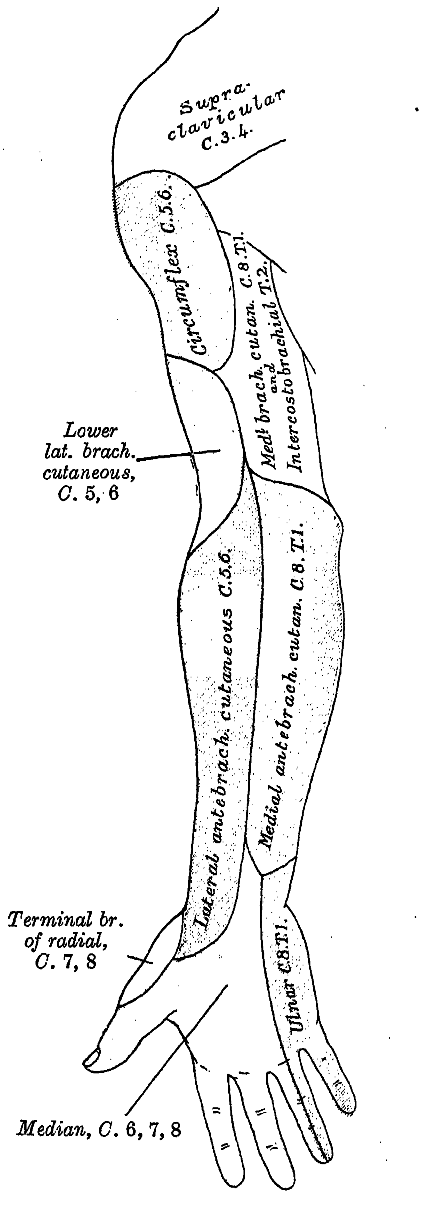


Fig. 973.—A diagram showing the segmental distribution of the cutaneous nerves of the right upper limb. Anterior surface.



to the ball of the thumb, where it ends in cutaneous filaments. It communicates with the terminal branch of the radial nerve, and with the palmar cutaneous branch of the median nerve.

The musculocutaneous nerve presents frequent irregularities. It may run behind the coracobrachialis or on rare occasions it may pass through the biceps. It may adhere for some distance to the median nerve and then pass behind the biceps instead of through the coracobrachialis. Some of the fibres of the

median nerve may run for some distance in the musculocutaneous nerve and then leave it to join their proper trunk ; less frequently the reverse is the case, and the median nerve sends a branch to join the musculocutaneous nerve. Occasionally it gives a filament to the pronator teres and, sometimes, it may replace the branches of the radial nerve to the dorsal surface of the thumb.

The **medial cutaneous nerve of the forearm** (fig. 976) arises from the medial cord of the brachial plexus. It derives its fibres from the eighth cervical and first thoracic nerves, and at its commencement is placed between the axillary artery and vein. Near the axilla it supplies a filament which pierces the fascia and is distributed to the skin covering the biceps, almost as far as the elbow. The nerve then runs down the arm on the medial side of the brachial artery, pierces the deep fascia with the basilic vein about the middle of the arm, and divides into an anterior and a posterior branch.

The *anterior branch*, the larger, passes usually in front of, but occasionally behind, the median cubital vein (median basilic vein). It then descends on the front of the medial side of the forearm, distributing filaments to the skin as far as the wrist, and communicating with the palmar cutaneous branch of the ulnar nerve (fig. 972).

The *posterior branch* passes obliquely downwards on the medial side of the basilic vein, in front of the medial epicondyle of the humerus, winds round to the back of the forearm, and descends on its medial side as far as the wrist, distributing filaments to the skin. It communicates with the medial cutaneous nerve of the arm, the posterior cutaneous nerve of the forearm, and the dorsal branch of the ulnar nerve (fig. 974).

The **medial cutaneous nerve of the arm** is distributed to the skin on the medial side of the arm (fig. 972). It is the smallest branch of the brachial plexus, and, arising from the medial cord, receives its fibres from the eighth cervical and first thoracic nerves. It passes through the axilla and crosses in front of, or behind, the axillary vein. It then runs on the medial side of this vein, and communicates with the intercostobrachial nerve. It descends along the medial side of the brachial artery to the middle of the upper arm, where it pierces the deep fascia, and is distributed to the skin of the dorsal surface of the lower one-third of the arm over its medial half, extending as far as the elbow ; some filaments are lost in the skin in front of the medial epicondyle, and others over the olecranon. It communicates with the posterior branch of the medial cutaneous nerve of the forearm.

In some subjects the medial brachial cutaneous and intercostobrachial nerves are connected by two or three filaments, which form a plexus in the axilla. In others the intercostobrachial nerve is large and may be reinforced by a part of the lateral cutaneous branch of the third intercostal nerve ; it then takes the place of the medial brachial cutaneous nerve, receiving from the brachial plexus a communicating filament which represents the latter nerve ; occasionally this filament is wanting.

The **median nerve** (fig. 976) arises by two roots, one from the lateral and the other from the medial cord of the brachial plexus ; these embrace the lower part of the axillary artery, uniting either in front or on the lateral side of that vessel. Its fibres are derived from the (fifth), sixth, seventh, and eighth cervical and first thoracic nerves. As the median nerve descends through the arm, it lies at first lateral to the brachial artery ; about the level of the insertion of the coracobrachialis it crosses in front of, occasionally behind, the artery, and then descends on its medial side to the bend of the elbow, where it is situated behind the bicipital aponeurosis (lacertus fibrosus), and is separated from the elbow-joint by the brachialis. It enters the forearm between the two heads of the pronator teres ; here it crosses the ulnar artery, but is separated from it by the deep head of the pronator teres. It passes behind the tendinous bridge which connects the humero-ulnar to the radial head of the flexor digitorum sublimis and descends through the forearm under cover of, and adherent to, that muscle, lying on the flexor digitorum profundus. About 5 cm. above the flexor retinaculum (transverse carpal ligament) it is crossed by the oblique lateral border of the radial head of the flexor digitorum sublimis and becomes more superficial. It now lies between the tendons of the flexor digitorum

sublimis and the flexor carpi radialis, behind, but rather to the lateral side of, the tendon of the palmaris longus. It then passes behind the flexor retinaculum and gains the palm of the hand. In its course through the forearm it is accompanied by the median artery, a branch of the anterior interosseous artery.

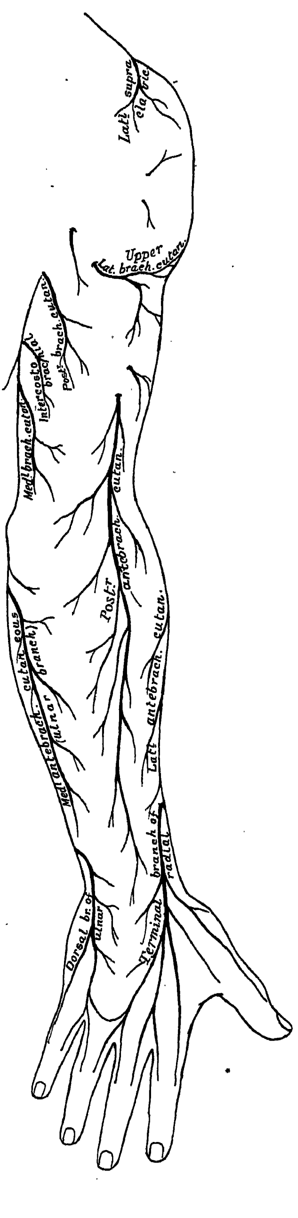


Fig. 974.—The cutaneous nerves of the right upper limb. Posterior surface.

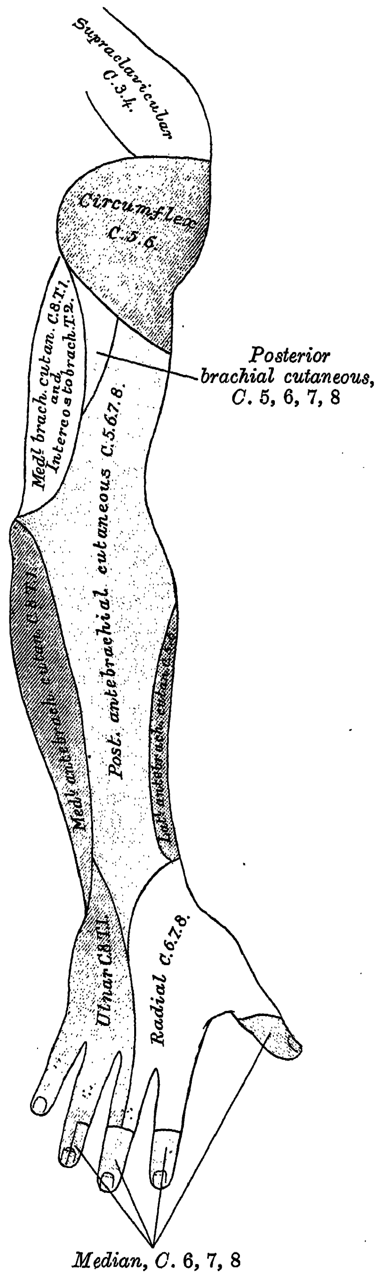


Fig. 975.—A diagram showing the segmental distribution of the cutaneous nerves of the right upper limb. Posterior surface.

Branches.—With the exception of the nerve to the pronator teres, which derives its fibres from the sixth cervical nerve and usually arises above the elbow-joint, the median nerve gives no branches in the arm. As it passes in front of the elbow, it supplies one or two twigs to the joint.

In the forearm its branches are : muscular, anterior interosseous, and palmar.

The *muscular branches* are derived from the nerve near the elbow and supply all the superficial muscles on the front of the forearm, except the flexor carpi ulnaris.

The *anterior interosseous nerve* accompanies the anterior interosseous artery along the front of the interosseous membrane of the forearm, in the interval between the flexor pollicis longus and flexor digitorum profundus, supplying the whole of the former and the lateral half of the latter muscle ; it sends branches into the deep surface of the pronator quadratus, and ends by supplying the wrist-joint.

The *palmar branch* of the median nerve arises at the lower part of the forearm. It pierces the deep fascia above the flexor retinaculum (transverse carpal ligament), and divides into a lateral and a medial branch ; the lateral branch supplies the skin over the thenar eminence, and communicates with the anterior branch of the lateral cutaneous nerve of the forearm ; the medial branch supplies the skin of the palm, and communicates with the palmar cutaneous branch of the ulnar nerve.

In the palm of the hand the median nerve is covered by the skin, the palmar aponeurosis and the superficial palmar arch, and rests on the tendons of the flexor muscles. Immediately after emerging from behind the flexor retinaculum it becomes enlarged and flattened, and splits into a lateral and a medial portion. The *lateral* portion of the nerve supplies a short, stout branch to the following muscles of the ball of the thumb, viz. the abductor brevis, the opponens and the flexor brevis, and then divides into three *palmar digital nerves* ; two of these supply the sides and the joints of the thumb, while the third gives a twig to the first lumbrical and is distributed to the radial side of the index finger. The *medial* portion of the nerve divides into two *palmar digital nerves*. The first of these gives a twig to the second lumbrical and runs towards the cleft between the index and middle fingers, where it divides into two collateral branches for the adjoining sides of these digits. The second runs towards the cleft between the middle and ring fingers, and splits into two collateral branches for the adjoining sides of these digits ; it receives a communicating branch from the ulnar nerve, and sometimes sends a twig to the third lumbrical.

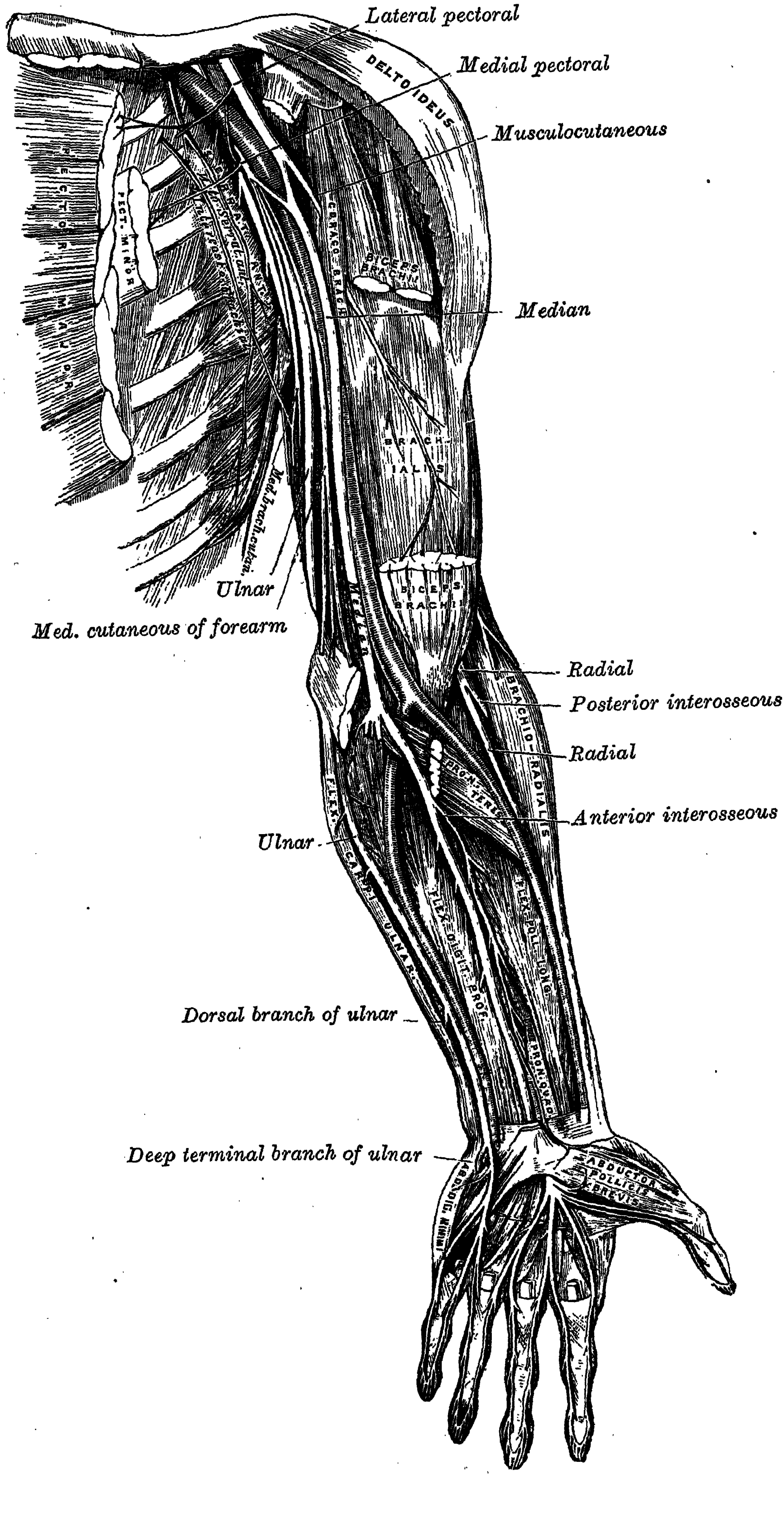
Opposite the base of the proximal phalanx, each collateral digital nerve gives off a dorsal branch, which joins the dorsal digital branch from the radial nerve, and supplies the skin on the dorsal surface of the phalanx. At the end of the digit, each collateral digital nerve divides into two branches ; one supplies the pulp of the finger, the other ramifies around and beneath the nail. On the fingers the collateral digital nerves are in front of the corresponding arteries, and they give articular twigs to the metacarpophalangeal and interphalangeal joints.

The **ulnar nerve** (fig. 976) arises from the medial cord of the brachial plexus, and derives its fibres from the seventh and eighth cervical and first thoracic nerves.* It runs downwards through the axilla on the medial side of the axillary artery, intervening between it and the axillary vein, and continues downwards on the medial side of the brachial artery as far as the middle of the upper arm. Here it pierces the medial intermuscular septum, and descends in front of the medial head of the triceps, to the interval between the medial epicondyle and the olecranon, accompanied by the (superior) ulnar collateral artery. At the elbow it lies in a groove on the back of the medial epicondyle, and as it enters the forearm between the two heads of the flexor carpi ulnaris, it lies on the posterior and oblique parts of the medial ligament (ulnar collateral ligament) of the elbow-joint. It descends along the medial side of the forearm, lying upon the flexor digitorum profundus ; its upper half is covered by the flexor carpi ulnaris ; its lower half lies on the lateral side of this muscle, and is covered by the skin and fasciæ. In the upper one-third of the forearm, the ulnar nerve

* Wilfred Harris (*Journal of Anatomy*, vol. xxxviii.) found a branch running from the seventh cervical nerve to the ulnar nerve in 86 per cent. of subjects, and believed, on clinical grounds, that the fibres of this branch were mainly motor to the Flexor carpi ulnaris.

E. A. Linell (*Journal of Anatomy*, vol. lv.) found a considerable bundle of seventh cervical nerve-fibres running from the lateral root of the median nerve to the ulnar nerve in 57 per cent. of subjects.

Fig. 976.—The nerves of the left upper limb.



is separated from the ulnar artery by a considerable interval, but in the rest of its extent it lies close to the medial side of the vessel. About 5 cm. above the wrist it gives off a dorsal branch, and it is then continued downwards into the hand, passing in front of the flexor retinaculum (transverse carpal ligament) on the lateral side of the pisiform bone and lying medial to and somewhat behind the ulnar artery. It passes behind the superficial part of the retinaculum (volar carpal ligament) and ends by dividing into a superficial and a deep terminal branch.

The branches of the ulnar nerve are: articular to the elbow-joint, muscular, palmar cutaneous, dorsal, and superficial terminal and deep terminal.

The *articular branches* to the elbow-joint are several small filaments which arise from the nerve as it lies between the medial epicondyle and olecranon.

The *muscular branches*, two in number, arise near the elbow; one supplies the flexor carpi ulnaris; the other, the medial half of the flexor digitorum profundus.

The *palmar cutaneous branch* arises about the middle of the forearm, and descends on the ulnar artery, giving some filaments to the vessel. It perforates the deep fascia and ends in the skin of the palm, after communicating with the palmar branch of the median nerve. It sometimes supplies the palmaris brevis.

The *dorsal branch* arises about 5 cm. above the wrist; it passes backwards deep to the flexor carpi ulnaris, perforates the deep fascia, and, running along the medial side of the back of the wrist and hand, divides into two, frequently three, dorsal digital nerves: one supplies the medial side of the little finger; the second the adjacent sides of the little and ring fingers. The third, when present, supplies the adjoining sides of the ring and middle fingers, but it may be replaced, wholly or partially, by a branch of the radial nerve, with which it always communicates on the dorsum of the hand. A branch is distributed to the metacarpal region of the hand, communicating with a twig from the radial nerve (fig. 974). On the little finger the dorsal digital nerves extend only as far as the base of the distal phalanx, and on the ring finger as far as the base of the middle phalanx; the more distal parts of these digits are supplied by dorsal branches derived from the collateral digital branches of the ulnar nerve.

The *superficial terminal branch* supplies the palmaris brevis and the skin on the medial side of the hand, and divides into two palmar digital nerves. One of these supplies the medial side of the little finger; the other sends a twig to join the median nerve and then divides into two collateral branches for the adjoining sides of the little and ring fingers (fig. 976). The collateral branches are distributed to the fingers in the same manner as those of the median nerve.

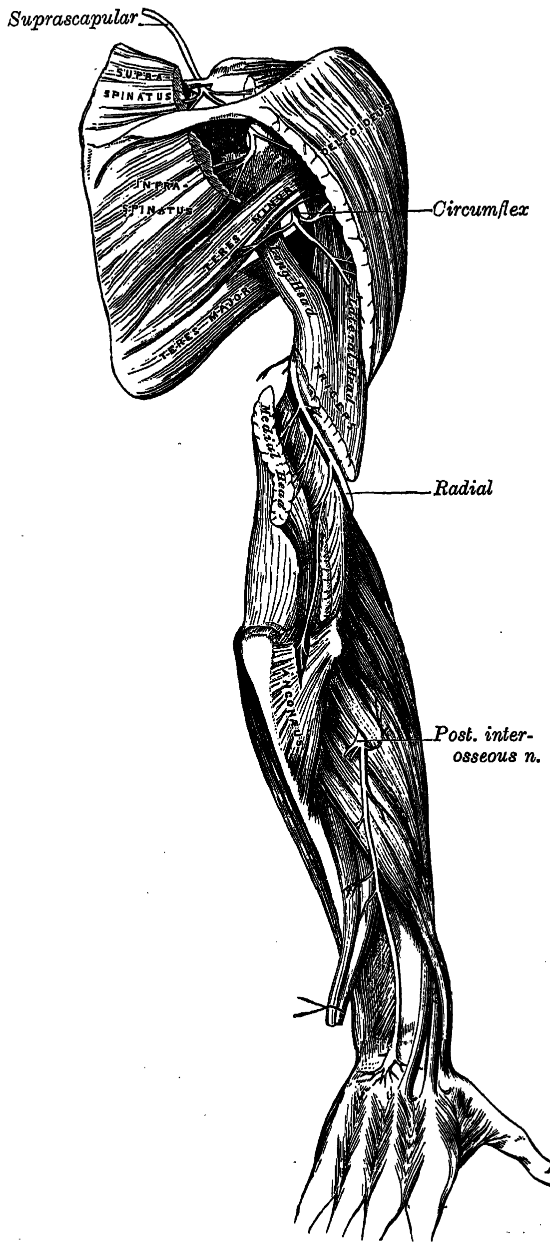
The *deep terminal branch*, accompanied by the deep branch of the ulnar artery, passes between the abductor digiti minimi and flexor digiti minimi; it then perforates the opponens digiti minimi and follows the course of the deep palmar arch behind the flexor tendons. At its origin it supplies the three short muscles of the little finger. As it crosses the hand, it gives branches to the interossei and to the third and fourth lumbricals; it ends by supplying the adductor pollicis and the first palmar interosseous muscle (deep portion of the flexor pollicis brevis). It also sends articular filaments to the wrist-joint.

It has been pointed out that the medial part of the flexor digitorum profundus is supplied by the ulnar nerve; the third and fourth lumbricals, which are connected with the tendons of this part of the muscle, are supplied by the same nerve. In like manner the lateral part of the flexor digitorum profundus and the first and second lumbricals are supplied by the median nerve. The third lumbrical frequently receives an additional twig from the median nerve.

The **radial nerve** (fig. 977), which is the largest branch of the brachial plexus, derives its fibres from the fifth, sixth, seventh, and eighth cervical and first thoracic nerves. It descends behind the third part of the axillary artery and the upper part of the brachial artery, and in front of the subscapularis and the tendons of the latissimus dorsi and teres major. Accompanied by the arteria profunda brachii it inclines backwards between the long and medial heads of the triceps, and passes obliquely across the back of the humerus in the spiral groove (sulcus nervi radialis), and under cover of the lateral

head of the triceps. On reaching the lateral side of the humerus it pierces the lateral intermuscular septum and enters the anterior compartment of the arm. It then descends, lying deeply in the intermuscular furrow which is bounded on the medial side by the brachialis and on the lateral side by the brachioradialis, above, and the extensor carpi radialis longus, below. On reaching the front of the lateral epicondyle it gives off the posterior interosseous nerve. It then descends along the front of the lateral side of the upper two-thirds of the forearm, lying at first upon the supinator, lateral to the radial artery, and behind the brachioradialis. In the middle one-third of the fore-arm, it lies behind the same muscle, but is now close to the lateral side of the artery. It quits the artery about 7 cm. above the wrist, passes deep to the tendon of the brachioradialis, and, piercing the deep fascia, divides into five, sometimes four, dorsal digital nerves, which are distributed as follows: the first supplies the skin of the radial side and ball of the thumb, communicating with branches of the lateral cutaneous nerve of the forearm; the second supplies the medial side of the thumb; the third, the lateral side of the index finger; the fourth, the adjoining sides of the index and middle fingers; the fifth communicates with a filament from the dorsal branch of the ulnar nerve, and supplies the adjoining sides of the middle and ring fingers,* but it is frequently replaced by the dorsal branch of the ulnar nerve. On the back of the hand the radial nerve usually communicates with the posterior and the lateral cutaneous nerves of the forearm.

Fig. 977.—The right suprascapular, circumflex, and radial nerves.



The branches of the radial nerve are: muscular, cutaneous, articular and the posterior interosseous nerve.

* According to Hutchison, the digital nerve to the thumb reaches only as far as the root of the nail; the one to the forefinger as far as the middle of the middle phalanx; and those to the middle and ring fingers not farther than the proximal interphalangeal joints.—*London Hospital Gazette*, vol. iii. p. 319.

The *muscular branches* supply the triceps, anconeus, brachioradialis, extensor carpi radialis longus and brachialis, and are grouped as medial, posterior and lateral.

The medial muscular branches arise from the radial nerve on the medial side of the arm and supply the medial and long heads of the triceps; the branch to the medial head is a long, slender filament, which lies close to the ulnar nerve as far as the lower one-third of the arm, and is therefore frequently named the *ulnar collateral nerve.*

The posterior muscular branch, of large size, arises from the nerve as it lies in the spiral groove (sulcus nervi radialis). It divides into filaments which supply the medial and lateral heads of the triceps and the anconeus. The branch for the latter muscle is a long nerve which descends in the substance of the medial head of the triceps, and gives numerous branches to it. It is accompanied by a branch of the arteria profunda brachii, and passes behind the elbow-joint to end in the anconeus.

The lateral muscular branches supply the brachioradialis, extensor carpi radialis longus and the lateral part of the brachialis.

The *cutaneous branches* are the posterior cutaneous and the lower lateral cutaneous nerves of the arm and the posterior cutaneous nerve of the forearm.

The *posterior cutaneous nerve of the arm,* of small size, arises in the axilla. It runs round the long head of the triceps to the medial side of the arm and supplies the skin on its dorsal surface nearly as far as the olecranon. It crosses posterior to, and communicates with, the intercostobrachial nerve.

The *lower lateral cutaneous nerve of the arm* perforates the lateral head of the triceps just below the insertion of the deltoid muscle. It then passes to the front of the elbow, lying close to the cephalic vein, and supplies the skin of the lateral part of the lower half of the arm (fig. 972). The *posterior cutaneous nerve of the forearm* arises in common with the preceding branch. After perforating the lateral head of the triceps, it descends along the lateral side of the arm, and then along the back of the forearm to the wrist, supplying the skin in its course, and joining, near its termination, with dorsal branches of the lateral cutaneous nerve of the arm (fig. 974).

The **articular branches** are distributed to the elbow-joint.

The **posterior interosseous nerve** (deep branch of the radial nerve) (fig. 977) winds to the back of the forearm round the lateral side of the radius between the two planes of fibres of the supinator. It gives a branch to the extensor carpi radialis brevis, and another to the supinator before it enters the latter muscle, and as it traverses its substance it supplies additional branches to it. As soon as it escapes from the supinator on the back of the forearm it gives off three short branches—to the extensor digitorum, extensor digiti minimi and extensor carpi ulnaris—and two long branches—a medial to the extensor pollicis longus and the extensor indicis, and a lateral which supplies the abductor pollicis longus and ends in the extensor pollicis brevis. The nerve lies at first between the superficial and the deep muscles of the back of the forearm, but, at the lower border of the extensor pollicis brevis, it passes deep to the extensor pollicis longus and, diminished to a fine thread, runs down on the dorsal aspect of the interosseous membrane of the forearm. Finally it reaches the back of the carpus, where it presents a flattened and somewhat expanded termination from which filaments are distributed to the ligaments and articulations of the carpus.

Applied Anatomy.—The brachial plexus may be injured by falls from a height on to the side of the head and shoulder, whereby the nerves of the plexus are violently stretched; the upper trunk of the plexus sustains the greatest amount of injury, and the subsequent paralysis may be confined to the muscles supplied by the fifth nerve, viz. the deltoid, biceps, brachialis and brachioradialis, with sometimes the supraspinatus, infraspinatus and supinator. The position of the limb, under such conditions, is characteristic: the arm hangs by the side and is rotated medially; the forearm is extended and pronated. The arm cannot be raised from the side; all power of flexion of the elbow is lost, as is also supination of the forearm. This is known as Erb's paralysis, and a very similar condition is occasionally met with in new-born children, either from injury to the upper trunk from the pressure of the forceps used in effecting delivery, or from traction of the head in breech presentations. A second variety of partial palsy of the brachial plexus is known as

Klumpke's paralysis. In this it is the eighth cervical and first thoracic nerves that are injured, either before or after they have joined to form the lower trunk. The subsequent paralysis affects, principally, the intrinsic muscles of the hand and the flexors of the wrist and fingers.

The brachial plexus may also be injured by direct violence or a gunshot wound, by violent traction on the arm, or by effort at reducing a dislocation of the shoulder-joint; and the amount of paralysis will depend upon the amount of injury to the constituent nerves. When the entire plexus is involved, the whole of the upper extremity will be paralysed and anæsthetic. In some cases the injury appears to be rather a tearing away of the roots of the nerves from the spinal cord than a rupture of the nerves themselves. The brachial plexus in the axilla is often damaged from the presence of a crutch, producing the condition known as 'crutch paralysis.' In these cases the radial is the nerve most frequently implicated; the ulnar nerve suffers next in frequency. The median and radial nerves often suffer from 'sleep palsies,' paralysis from pressure coming on while the patient is profoundly asleep under the influence of alcohol or some narcotic.

Paralysis of the *nerve to serratus anterior* (long thoracic nerve) throws that muscle out of action, and may occur in porters, in whom the nerve is exposed to injury as it lies in the posterior triangle of the neck. The inferior angle of the scapula is drawn towards the median plane, by the unopposed action of the rhomboids and levator scapulæ, and tends to project backwards when the arm is held horizontally forwards. The arm cannot be raised above the horizontal unless the inferior angle of the scapula is pushed laterally and forwards for the patient.

The *circumflex nerve* (axillary nerve), on account of its course round the surgical neck of the humerus, is liable to be torn in fractures of this part of the bone, and in dislocations of the shoulder-joint; paralysis of the deltoid, and anæsthesia of the skin over the lower part of that muscle, result. Paralysis of the deltoid renders complete abduction of the arm impossible. The associated paralysis of the teres minor is not easily demonstrated.

The *median nerve* is liable to injury in wounds of the forearm. When it is completely divided above the origin of its muscular and anterior interosseous branches, there is loss of flexion of the second phalanges of all the fingers, and of the terminal phalanges of the index and middle fingers. Flexion of the terminal phalanges of the ring and little fingers is effected by that portion of the flexor digitorum profundus which is supplied by the ulnar nerve. There is power to flex the proximal phalanges through the interossei. The thumb cannot be flexed, opposed or abducted, and is maintained in a position of extension and adduction. There is loss in the power of pronating the forearm; the brachioradialis has the power of bringing the forearm into a position of mid-pronation, but beyond this no further pronation can be effected. The wrist can be flexed by the flexor carpi ulnaris, but flexion is combined with adduction of the hand. There is loss or impairment of sensation on the palmar surfaces of the thumb, index, middle, and radial half of the ring fingers, and on the dorsal surfaces of the same fingers over the last two phalanges; except in the thumb, where the loss of sensation is limited to the back of the distal phalanx. Owing to the paralysis of the short muscles of the thumb which has already been described, an 'ape-like' hand is produced. More commonly, however, the nerve is injured just above the flexor retinaculum (transverse carpal ligament), when the power of flexion of the fingers and pronation of the forearm remains intact, unless the flexor tendons are also divided.

The *ulnar nerve* is also liable to be injured in wounds of the forearm, such injury leading to impaired power of ulnar flexion, and upon an attempt being made to flex the wrist, the hand is drawn to the radial side by the flexor carpi radialis; there is inability to spread out the fingers from paralysis of the interossei, and for the same reason the fingers, especially the ring and little fingers, cannot be flexed at the metacarpophalangeal joints or extended at the interphalangeal joints, and the hand assumes a claw shape from the action of the opposing muscles; there is loss of power of flexion in the little and ring fingers; and there is inability to adduct the thumb. The muscles of the hypothenar eminence become wasted. Sensation is lost, or impaired, in the skin supplied by the nerve. Wasting of the muscles which it supplies is not uncommonly seen where a 'cervical rib' is present, the lower end of the plexus passing across its upper surface.

The *radial nerve* also is frequently injured. In consequence of its close relationship to the humerus, it is often torn or injured in fractures of this bone, or subsequently involved during the repair of the fracture, and its functions are interfered with. It is also liable to be contused against the bone by kicks or blows, or to be divided in wounds of the arm. When paralysed, the hand is flexed at the wrist and lies flaccid. This is known as *wrist-drop*. The fingers are also flexed, and when an attempt is made to extend them, the last two phalanges only will be extended, through the action of the lumbrical and interosseous muscles; the first phalanges remain flexed. Extension of the wrist is impossible. Supination is completely lost when the forearm is extended on the arm, but is possible to a certain extent if the forearm be flexed so as to allow of the action of the biceps. The power of extension of the forearm is lost on account of paralysis of the triceps, if the injury to the nerve has taken place near its origin. As the radial nerve has only a very small area of exclusive supply, the extent of the anæsthesia associated with

severe injuries to the nerve is surprisingly small and is confined to a limited region on the lateral part of the dorsum of the hand.

Occasionally the whole plexus is moved up one segment. In this event the contribution of the fourth cervical nerve is large and that from the first thoracic nerve correspondingly small. The condition is termed "pre-fixation" of the plexus. The opposite condition, in which the whole plexus is moved one segment caudally, is termed "post-fixation" of the plexus. It is characterised by a large contribution from the second thoracic nerve, and a correspondingly small contribution from the fifth cervical.

THE ANTERIOR PRIMARY RAMI OF THE THORACIC NERVES

The **anterior primary rami of the thoracic nerves** (fig. 978) are twelve in number on each side. Eleven of them are situated between the ribs, and are therefore termed *intercostal*; the twelfth lies below the last rib and is frequently termed the *subcostal nerve*. Each nerve is connected with the adjoining ganglion of the sympathetic trunk by a grey and a white ramus communicans; occasionally these two rami are enclosed in a common sheath, but, as a rule, they remain separate and the grey ramus joins the nerve proximal to the point at which the white ramus leaves it. The intercostal nerves are distributed chiefly to the parietes of the thorax and abdomen. The first two nerves supply fibres to the upper limb in addition to their thoracic branches; the next four are limited in their distribution to the parietes of the thorax; the lower five supply parietes of the thorax and abdomen; the lower seven supply fibres to the diaphragm; the subcostal nerve is distributed to the abdominal wall and the skin of the buttock. Communicating branches link the intercostal nerves to one another in the posterior parts of the intercostal spaces and, in addition, the lower five communicate freely as they traverse the abdominal wall.*

The upper thoracic nerves.—The anterior primary ramus of the first thoracic nerve divides into a large and a small branch. The large branch ascends in front of the neck of the first rib on the lateral side of the superior intercostal artery, and enters the brachial plexus (p. 1093). The small branch is the *first intercostal nerve*; it runs along the first intercostal space, and ends on the front of the chest as the first anterior cutaneous branch of the thorax. Occasionally this small anterior cutaneous branch is wanting. The first intercostal nerve as a rule gives off no lateral cutaneous branch; but sometimes it sends a small branch to communicate with the intercostobrachial. The first thoracic nerve frequently receives a connecting twig from the second nerve; this twig ascends in front of the neck of the second rib.

The anterior primary rami of the second, third, fourth, fifth, and sixth thoracic nerves pass forwards (fig. 979) in the intercostal spaces below the intercostal vessels. At the back of the chest they lie between the pleura and the posterior intercostal membranes, but in most of their course they run between the internal intercostal muscles and the intercostales intimi (intracostales) (p. 553). Where the latter muscles are absent, the nerves lie in contact with the parietal pleura. Near the sternum, they cross in front of the internal mammary artery and sternocostalis (transversus thoracis) muscle, pierce the internal intercostals, the anterior intercostal membranes, and the pectoralis major, and are now named the *anterior cutaneous nerves of the thorax*; they supply the skin of the front of the thorax; the anterior cutaneous branch of the second nerve may be connected to the medial supraclavicular nerves of the cervical plexus.

Branches.—Numerous slender muscular filaments supply the intercostal muscles, the levatores costarum, the serratus posterior superior, and the sternocostalis. At the front of the thorax some of these branches cross the costal cartilages from one intercostal space to another.

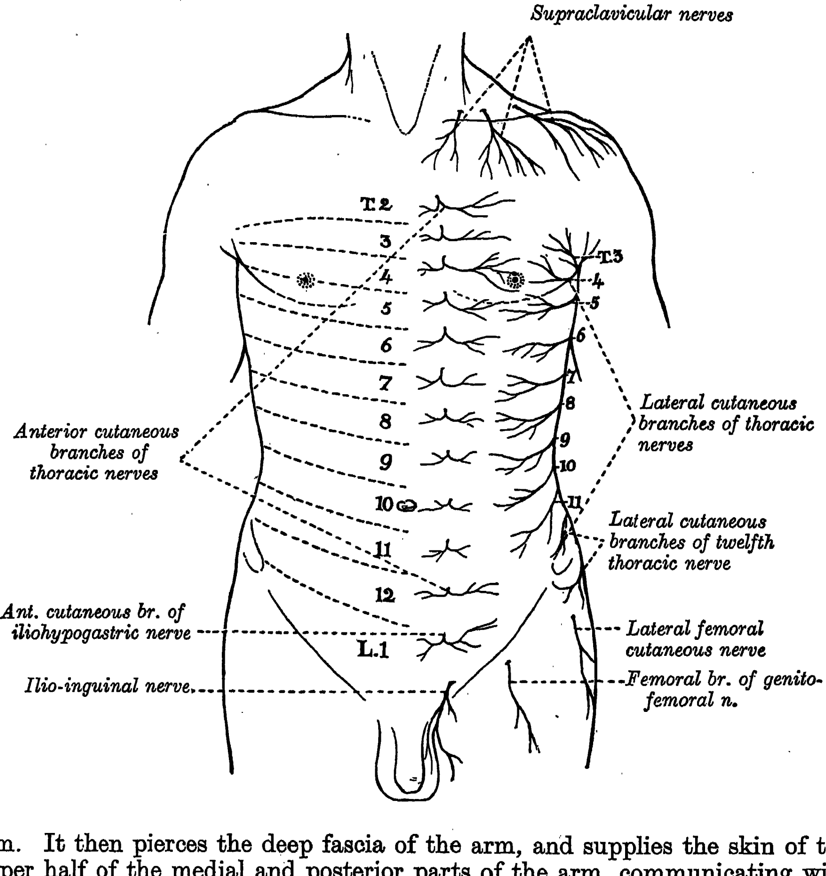
Each intercostal nerve, except the first, gives off a *collateral branch** and a *lateral cutaneous branch* before it reaches the angle of the rib. The collateral branch follows the lower border of the space in the same intermuscular interval as the main trunk, which it may, or may not, rejoin before it is distributed as

* F. Davies, R. J. Gladstone and E. P. Stibbe, *Journal of Anatomy*, vol. lxvi. 1932.

an additional anterior cutaneous nerve. The lateral cutaneous branch accompanies the main trunk for a time and then pierces the intercostal muscles obliquely. With the exception of the lateral cutaneous branch of the second intercostal nerve, each divides into anterior and posterior branches, which subsequently pierce the serratus anterior muscle. The *anterior branches* run forwards over the border of the pectoralis major and supply twigs to the overlying skin; those of the fifth and sixth nerves supply twigs to the upper digitations of the external oblique muscle. The *posterior branches* run backwards, and supply the skin over the scapula and latissimus dorsi.

The lateral cutaneous branch of the second intercostal nerve is named the *intercostobrachial nerve* (fig. 976). It crosses the axilla to gain the medial side of the arm, and joins with a filament from the medial cutaneous nerve of the

FIG. 978.—A diagram showing the distribution of the cutaneous nerves on the front of the trunk.



arm. It then pierces the deep fascia of the arm, and supplies the skin of the upper half of the medial and posterior parts of the arm, communicating with the posterior brachial cutaneous branch of the radial nerve. The size of the intercostobrachial nerve is in inverse proportion to that of the medial brachial cutaneous nerve. A second intercostobrachial nerve is frequently given off from the anterior part of the lateral cutaneous branch of the third intercostal nerve; it supplies filaments to the axilla and to the medial side of the arm.

The lower thoracic nerves.—The anterior primary rami of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves are continued anteriorly from the intercostal spaces into the abdominal wall.

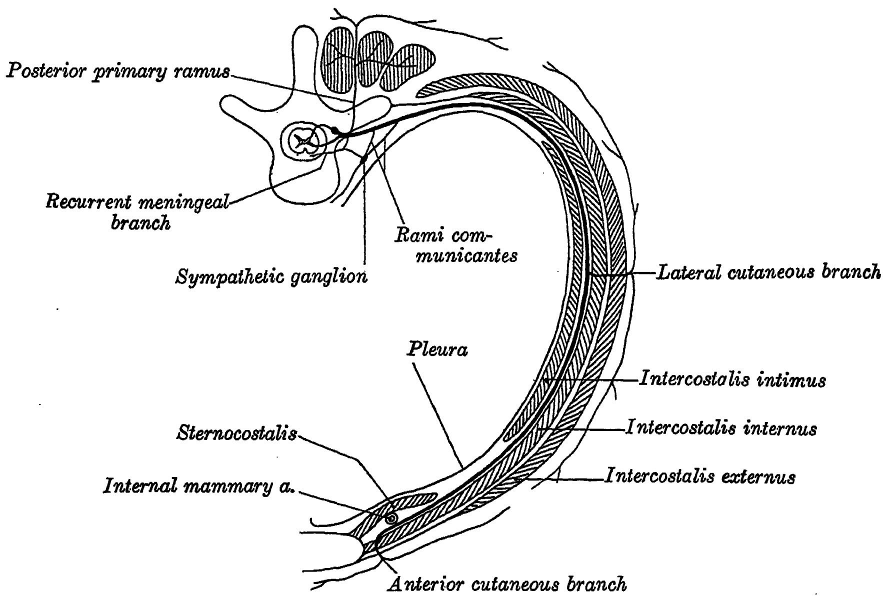
As they approach the anterior ends of the spaces in which they lie, the seventh and eighth nerves curve *upwards* and medially across the deep surface of the costal margin, insinuating themselves between the digitations of the transversus abdominis to gain the deep aspect of the posterior lamella of the aponeurosis of the internal oblique. Having pierced this layer, they lie behind the rectus abdominis muscle and continue upwards and medially (fig. 980) for a

short distance parallel with the costal margin. Both supply the rectus abdominis and, having passed through the muscle near its lateral edge, pierce the anterior wall of its sheath, to reach and supply the skin. It will be observed that both the seventh and the eighth intercostal nerves cross the costal margin medial to the lateral border of the rectus abdominis and therefore enter its sheath by piercing its posterior wall.

The ninth, tenth and eleventh intercostal nerves pass between the digitations of the transversus abdominis to gain the interval between that muscle and the internal oblique. In this intermuscular interval the ninth nerve runs almost *horizontally*, but the tenth and eleventh nerves run definitely downwards and medially. When they reach the lateral edge of the rectus abdominis, they pierce the posterior lamella of the internal oblique aponeurosis and pass behind the muscle. They end like the terminal branches of the seventh and eighth intercostal nerves.

The lower intercostal nerves supply the intercostal, the subcostal and the abdominal muscles, and the last three send branches to the serratus posterior

FIG. 979.—A diagram of the course of a typical intercostal nerve. The muscular and the collateral branches are not shown.

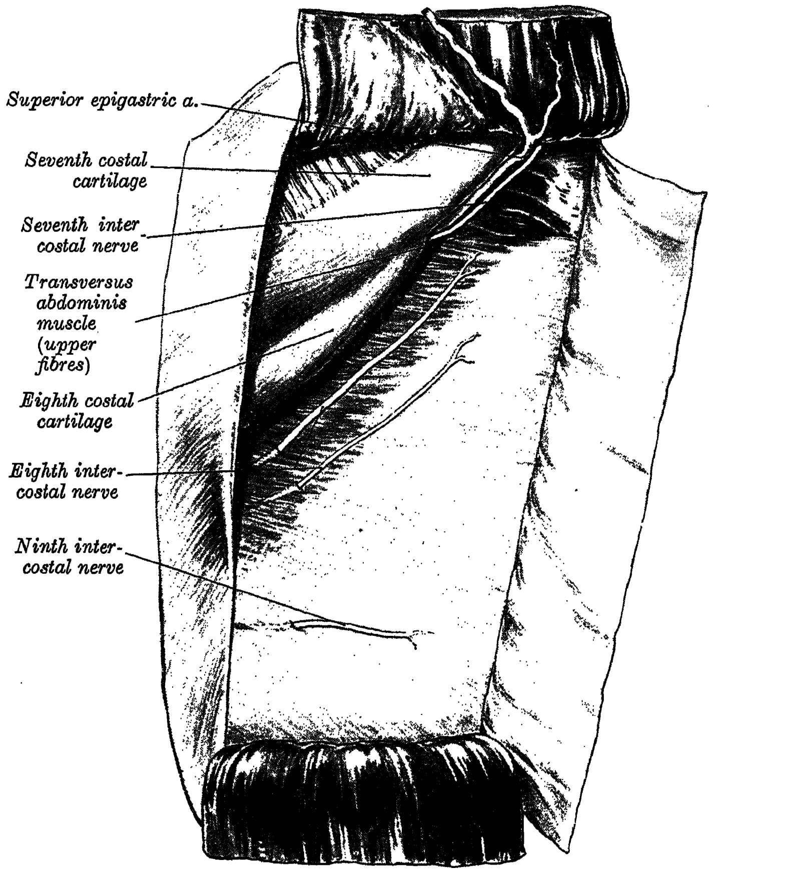


inferior. Like the upper intercostal nerves the lower intercostal nerves give off *collateral* and *lateral cutaneous branches* before they reach the angles of the ribs. The collateral branch may, or may not, rejoin the main trunk, but, if it does so, it leaves it again near the lateral border of the rectus abdominis and runs forwards below it (fig. 980). It pierces the muscle and the anterior wall of its sheath near the linea alba and supplies the skin. The lateral cutaneous branches pierce the intercostals and the external oblique muscle, in the same line as the lateral cutaneous branches of the upper thoracic nerves, and divide into anterior and posterior branches, which are distributed to the skin of the abdomen and back respectively; the anterior branches also supply twigs to the digitations of the external oblique muscle, and extend downwards and forwards nearly as far as the margin of the rectus abdominis; the posterior branches pass backwards to supply the skin over the latissimus dorsi. Each lateral cutaneous branch descends as it pierces the external oblique muscle and the superficial fascia so that it reaches the skin on a level with the corresponding anterior cutaneous branch and the cutaneous branch of the corresponding posterior primary ramus (p. 1087).

The anterior primary ramus of the twelfth thoracic nerve is larger than the others, and often gives a communicating branch to the first lumbar nerve.

Like the intercostal nerves it soon gives off a collateral branch. It accompanies the subcostal artery along the lower border of the twelfth rib, and passes behind the lateral arcuate ligament (lateral lumbocostal arch). It then runs behind the kidney, and in front of the upper part of the quadratus lumborum, perforates the aponeurosis of origin of the transversus, and passes forwards between that muscle and the obliquus internus, to be distributed in the same manner as the lower intercostal nerves. It communicates with the iliohypogastric nerve of the lumbar plexus, and gives a branch to the pyramidalis. The *lateral cutaneous branch* of the twelfth thoracic nerve pierces the internal and

FIG. 980.—A dissection to show the courses taken by the seventh, eighth and ninth intercostal nerves of the right side, after they enter the sheath of the rectus abdominis muscle.



The rectus abdominis muscle has been cut across; its upper part has been turned upwards, exposing most of the seventh and the anterior end of the eighth costal cartilage; its lower part has been turned downwards, exposing the posterior wall of the sheath.

external oblique muscles, gives a twig to the lowest slip of the latter, descends over the iliac crest about 5 cm. behind the anterior superior iliac spine (fig. 987), and is distributed to the skin of the front part of the buttock, some of its filaments reaching as low as the greater trochanter of the femur.

Applied Anatomy.—The lower seven thoracic nerves and the iliohypogastric branch of the first lumbar nerve supply the skin of the abdominal wall The sixth and seventh supply the skin over the 'pit of the stomach'; the eighth corresponds to about the position of the middle tendinous intersection of the rectus abdominis; the tenth to the umbilicus; the iliohypogastric supplies the skin over the pubis and superficial inguinal ring. In many diseases affecting the nerve-trunks at or near their origins, the pain is referred to their peripheral terminations. Thus, in Pott's disease of the vertebræ, children often suffer from pain in the abdomen. When the irritation is confined to a single pair of nerves the

sensation complained of is often a feeling of constriction, as if a cord were tied round the abdomen, and in these cases the situation of the sense of constriction may serve to localise the disease in the vertebral column. Where the bone disease is more extensive and two or more nerves are involved, a more general, diffused pain in the abdomen is felt.

Again, it must be borne in mind that the nerves which supply the skin of the abdomen supply also the planes of muscle which constitute the greater part of the abdominal wall. Hence, any irritation applied to the peripheral ends of the cutaneous branches in the skin of the abdomen is immediately followed by reflex contraction of the abdominal muscles. The supply of both muscles and skin from the same source is of importance in protecting the abdominal viscera from injury. A blow on the abdomen, even of a severe character, will do no injury to the viscera if the muscles are in a condition of firm contraction ; whereas in cases where the muscles have been taken unawares, and the blow has been struck while they were in a state of rest, an injury insufficient to produce any lesion of the abdominal wall has been attended with rupture of some of the abdominal contents. The importance, therefore, of immediate reflex contraction upon the receipt of an injury cannot be overestimated, and the intimate association of the cutaneous and muscular fibres in the same nerve produces a much more rapid response on the part of the muscles to any peripheral stimulation of the cutaneous filaments than would be the case if the two sets of fibres were derived from independent sources.

The nerves supplying the abdominal muscles and skin, derived from the lower intercostal nerves, are intimately connected with the sympathetic nerves supplying the abdominal viscera through the lower thoracic ganglia, from which the splanchnic nerves are derived. In consequence of this, in laceration of the abdominal viscera, and in acute peritonitis, the muscles of the belly wall become firmly contracted, and thus as far as possible preserve the abdominal contents in a condition of rest.

THE ANTERIOR PRIMARY RAMI OF THE LUMBAR NERVES

The **anterior primary rami of the lumbar nerves** increase in size from the first to the last. They are joined, near their origins, by *grey rami communicantes* from the lumbar ganglia of the sympathetic trunk. These rami consist of long, slender branches which accompany the lumbar arteries round the sides of the vertebral bodies, under cover of the psoas major. Their arrangement is somewhat irregular : one ganglion may give rami to two lumbar nerves, or one lumbar nerve may receive rami from two ganglia : not infrequently the rami arise from the sympathetic trunk between two ganglia. The first and second, and sometimes the third, lumbar nerves are each connected with the lumbar part of the sympathetic trunk by a *white ramus communicans.*

The anterior primary rami of the lumbar nerves pass downwards and laterally behind the psoas major, or between its fasciculi. The first three nerves and the greater part of the fourth, form the *lumbar plexus.* The smaller part of the fourth nerve * joins with the fifth to form the *lumbosacral trunk,* which assists in the formation of the sacral plexus.

The Lumbar Plexus

The **lumbar plexus** (fig. 981) is situated in the posterior part of the psoas major, in front of the transverse processes of the lumbar vertebræ ; it is formed by the anterior primary rami of the first three lumbar nerves and the greater part of the anterior primary ramus of the fourth ; the first lumbar nerve receives a branch from the last thoracic nerve.

The mode in which it is arranged varies in different subjects, but the usual condition is the following. The first lumbar nerve, supplemented by a twig from the last thoracic, splits into an upper and a lower branch ; the upper,

* The fourth nerve is named the *nervus furcalis,* from the fact that it is subdivided between the two plexuses. In most cases the fourth lumbar is the *nervus furcalis* ; but this arrangement is frequently departed from. The third is occasionally the lowest nerve which enters the lumbar plexus, giving at the same time some fibres to the sacral plexus, and thus forming the nervus furcalis ; or both the third and fourth may be furcal nerves. When this occurs, the plexus is termed *high* or *prefixed.* More frequently the fifth nerve is divided between the lumbar and sacral plexuses, and constitutes the nervus furcalis ; and when this takes place, the plexus is distinguished as a *low* or *postfixed* plexus. These variations necessarily produce corresponding modifications in the sacral plexus.

larger branch divides into the iliohypogastric and ilio-inguinal nerves; the lower, smaller branch unites with a branch of the second lumbar to form the genitofemoral nerve. The remainder of the second nerve, the third nerve, and the part of the fourth nerve which joins the plexus, divide into ventral and dorsal branches. The ventral branch of the second unites with the ventral branches of the third and fourth nerves to form the obturator nerve. The dorsal branches of the second and third nerves each divide into a smaller and larger part; the smaller parts unite to form the lateral femoral cutaneous nerve, and the larger parts join with the dorsal branch of the fourth nerve to form the femoral nerve. The accessory obturator, when it exists, arises from the ventral branches of the third and fourth nerves.

The branches of the lumbar plexus may therefore be arranged as follows:

Muscular	12 T., 1, 2, 3, 4 L.
Iliohypogastric	1 L.
Ilio-inguinal	1 L.
Genitofemoral	1, 2 L.
	Dorsal divisions.
Lateral femoral cutaneous	2, 3 L.
Femoral	2, 3, 4 L.
	Ventral divisions.
Obturator	2, 3, 4 L.
Accessory obturator	3, 4 L.

Muscular branches are distributed to the quadratus lumborum from the twelfth thoracic and first three or four lumbar nerves; to the psoas minor from the first, and to the psoas major and iliacus from the second, third and fourth lumbar nerves.

The **iliohypogastric nerve** arises from the first lumbar nerve (fig. 981). It emerges from the upper part of the lateral border of the psoas major, and crosses obliquely behind the lower part of the kidney, and in front of the quadratus lumborum. Just above the iliac crest it perforates the posterior part of the transversus abdominis, and divides between that muscle and the obliquus internus abdominis into a lateral and an anterior cutaneous branch.

The *lateral cutaneous branch* pierces the internal and external oblique muscles immediately above the iliac crest at a point a little behind the iliac branch of the twelfth thoracic nerve; it is distributed to the skin of the anterior part of the side of the buttock.

The *anterior cutaneous branch* (fig. 978) runs between the obliquus internus and transversus, supplying twigs to both muscles. It then pierces the obliquus internus at a point about 2 cm. on the medial side of the anterior superior iliac spine, perforates the aponeurosis of the external oblique about 3 cm. above the superficial inguinal ring, and is distributed to the skin of the abdomen above the pubis.

The iliohypogastric nerve communicates with the last thoracic and ilio-inguinal nerves.

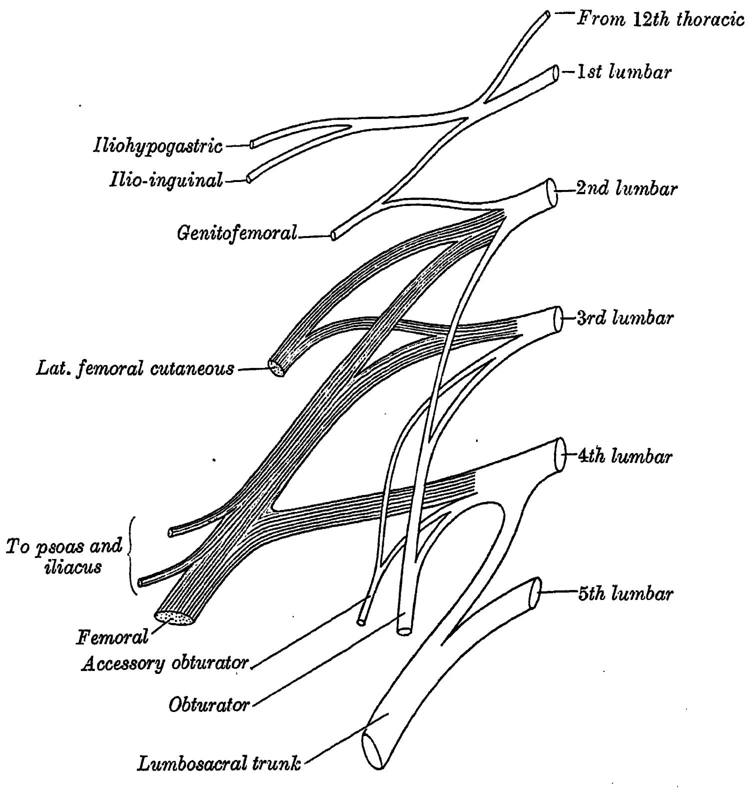
The **ilio-inguinal nerve**, smaller than the iliohypogastric nerve, arises with it from the first lumbar nerve (fig. 981). It emerges from the lateral border of the psoas major, with or just below the iliohypogastric nerve, and, passing obliquely across the quadratus lumborum and the upper part of the iliacus, perforates the transversus abdominis, near the anterior part of the iliac crest, and communicates with the iliohypogastric nerve. It then pierces the internal oblique muscle, distributing filaments to it, and, accompanying the spermatic cord through the superficial inguinal ring, is distributed to the skin of the upper and medial part of the thigh, to the skin over the root of the penis and upper part of the scrotum in the male (fig. 978), and to the skin covering the mons pubis and labium majus in the female.

The size of the ilio-inguinal nerve is in inverse proportion to that of the iliohypogastric. Occasionally it is very small, and ends by joining the iliohypogastric nerve; in such cases, a branch from the iliohypogastric takes the place of the ilio-inguinal, or the latter nerve may be altogether absent. On the analogy of the intercostal nerves the ilio-inguinal nerve may be regarded as the collateral branch (p. 1107) of the first lumbar nerve, and the iliohypogastric as the main trunk, which gives off the lateral cutaneous branch.

The **genitofemoral nerve** arises from the first and second lumbar nerves (fig. 981). It passes obliquely forwards and downwards through the substance of the psoas major, and emerges near its medial border, opposite the third or fourth lumbar vertebra; it then descends on the surface of the psoas major, under cover of the peritoneum, and, crossing obliquely behind the ureter, divides at a variable distance above the inguinal ligament into the genital (external spermatic) and femoral (lumbo-inguinal) branches. The genitofemoral nerve frequently divides close to its origin, and its two branches then emerge separately through the psoas major.

The *genital branch* (external spermatic nerve) crosses the lower end of the external iliac artery, and enters the inguinal canal through the deep inguinal

Fig. 981.—A plan of the lumbar plexus.



ring; it supplies the cremaster, and gives a few filaments to the skin of the scrotum. In the female, it accompanies the round ligament of the uterus and ends in the skin of the mons pubis and labium majus.

The *femoral branch* (lumbo-inguinal nerve) descends on the lateral side of the external iliac artery, and sends a few filaments round it; it then crosses the deep circumflex iliac artery, and, passing behind the inguinal ligament, enters the femoral sheath, lying lateral to the femoral artery. It pierces the anterior layer of the femoral sheath and the fascia lata, and supplies the skin over the upper part of the femoral triangle (fig. 982). It communicates with the intermediate cutaneous nerve of the thigh, and gives a few twigs to the femoral artery.

The **lateral cutaneous nerve of the thigh** arises from the dorsal branches of the anterior primary rami of the second and third lumbar nerves (fig. 981). It emerges from the lateral border of the psoas major, and crosses the iliacus obliquely, running towards the anterior superior iliac spine. On the right side the nerve passes behind and lateral to the cæcum, from which it is separated by the fascia iliaca and the peritoneum; on the left side, it passes behind the lower part of the descending colon. It then passes behind the inguinal ligament

and in front of or through the sartorius into the thigh, where it divides into an anterior and a posterior branch (fig. 982).

Fig. 982.—The cutaneous nerves of the right lower limb. Anterior surface.

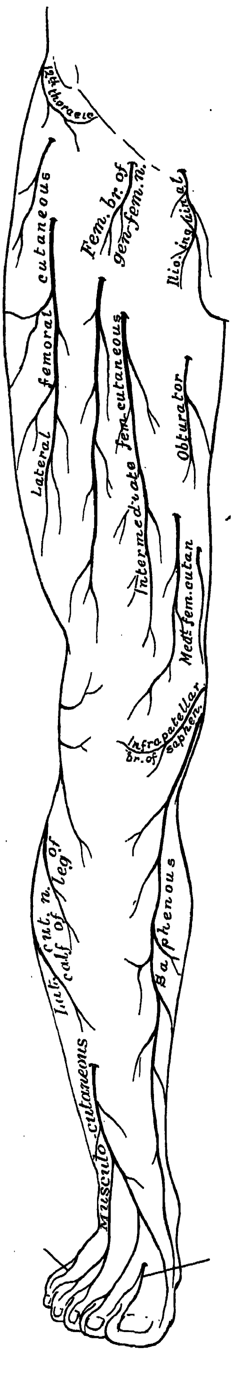
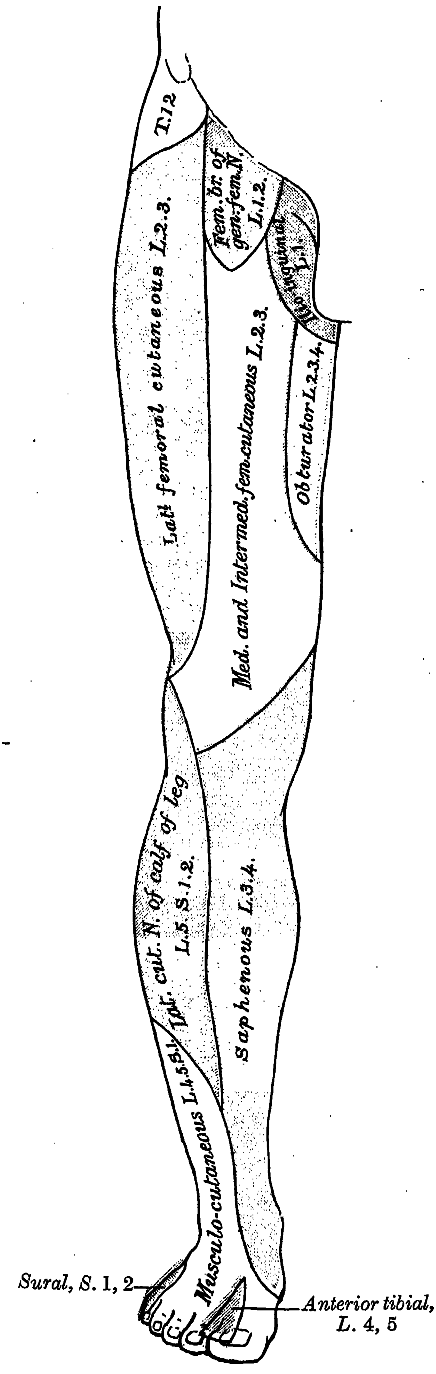


Fig. 983.—A diagram showing the segmental distribution of the cutaneous nerves of the right lower limb. Anterior surface.



The *anterior branch* becomes superficial about 10 cm. below the anterior superior iliac spine, and is distributed to the skin of the anterior and lateral parts of the thigh, as far as the knee. Its terminal filaments frequently com-

municate with the cutaneous branches of the anterior division of the femoral nerve and with the infrapatellar branch of the saphenous nerve, forming with them the *patellar plexus*.

The *posterior branch* pierces the fascia lata at a higher level than the anterior branch, and subdivides into filaments which pass backwards to supply the skin on the lateral surface of the limb, from the level of the greater trochanter to about the middle of the thigh.

The **obturator nerve** arises from the ventral branches of the anterior primary rami of the second, third, and fourth lumbar nerves (fig. 981) ; the branch from the third is the largest, while that from the second is often very small. It descends through the fibres of the psoas major, and emerges from its medial border at the brim of the pelvis, where it passes behind the common iliac vessels, and on the lateral side of the internal iliac vessels. It then runs downwards and forwards along the lateral wall of the true pelvis, above and in front of the obturator vessels, to gain the upper part of the obturator foramen, through which it enters the thigh. At the foramen it divides into an anterior and a posterior branch, which are separated at first by a few fibres of the obturator externus, and lower down by the adductor brevis.

The *anterior branch* (fig. 984) leaves the pelvis in front of the obturator externus and descends in front of the adductor brevis, and behind the pectineus and adductor longus ; at the lower border of the latter muscle it communicates with the medial cutaneous and saphenous branches of the femoral nerve, forming a kind of plexus (subsartorial plexus). It then descends upon the femoral artery, to which it is finally distributed. Near the obturator foramen this branch gives an articular twig to the hip-joint. Behind the pectineus, it distributes branches to the adductor longus and gracilis, and usually to the adductor brevis, and in rare cases to the pectineus ; it receives a filament from the accessory obturator nerve when that nerve is present.

Occasionally the communicating branch to the medial cutaneous and saphenous branches of the femoral nerve is continued down, as a cutaneous branch, to the thigh and leg. When this is so, it emerges from behind the lower border of the adductor longus, descends along the posterior margin of the sartorius to the medial side of the knee, where it pierces the deep fascia, communicates with the saphenous nerve, and is distributed to the skin halfway down the medial side of the leg.

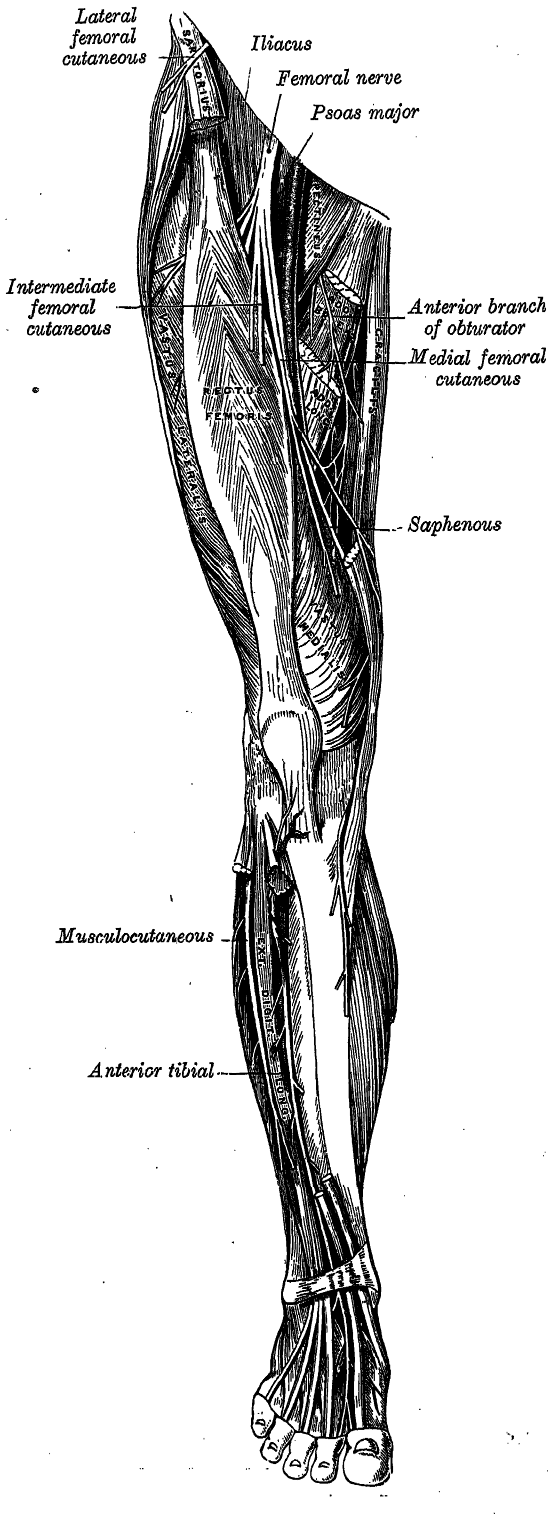
The *posterior branch* pierces the anterior part of the obturator externus, and supplies this muscle ; it then passes behind the adductor brevis on the front of the adductor magnus, and divides into branches which are distributed to the adductor magnus, and to the adductor brevis when this muscle does not receive a branch from the anterior division of the nerve. It frequently gives a slender *articular branch* to the knee-joint ; this branch perforates the lower part of the adductor magnus or passes through the opening which transmits the femoral artery, and enters the popliteal fossa ; it here descends upon the popliteal artery, to the back of the knee-joint, where it pierces the oblique posterior ligament of the knee, and is distributed to the articular capsule. It gives filaments to the popliteal artery.

The **accessory obturator nerve** (fig. 981) is present in about 29 per cent. of subjects. It is of small size, and arises from the ventral branches of the anterior primary rami of the third and fourth lumbar nerves. It descends along the medial border of the psoas major, crosses the superior ramus of the pubis behind the pectineus, and divides into branches. One branch enters the deep surface of the pectineus ; another goes to the hip-joint ; while a third communicates with the anterior branch of the obturator nerve. Occasionally the accessory obturator nerve is very small and supplies only the pectineus.

The **femoral nerve** (fig. 984), the largest branch of the lumbar plexus, arises from the dorsal branches of the anterior primary rami of the second, third and fourth lumbar nerves (fig. 981). It descends through the fibres of the psoas major, emerging from the muscle at the lower part of its lateral border, and passes down between it and the iliacus, deep to the iliac fascia ; it then passes behind the inguinal ligament to enter the thigh, and splits into an anterior and a posterior division. Behind the inguinal ligament it is separated from the femoral artery by a portion of the psoas major.

Within the abdomen the femoral nerve gives off small branches to the iliacus, the nerve to the pectineus, and a branch which is distributed upon the upper part of the femoral artery; the latter branch may arise in the thigh. The *nerve to the pectineus* arises from the medial side of the femoral nerve near the inguinal ligament, passes behind the femoral sheath and enters the anterior surface of the muscle.

Fig. 984.—The nerves of the right lower limb. Anterior surface.



The anterior division of the femoral nerve gives off the intermediate and medial cutaneous nerves of the thigh (fig. 982), and muscular branches to the sartorius.

The *intermediate cutaneous nerve of the thigh* pierces the fascia lata about 8 cm. below the inguinal ligament, either as two branches, or as a single trunk which quickly divides into two branches; these branches descend vertically along the front of the thigh, and supply the skin as low as the knee. They end in the patellar plexus (p. 1115). The lateral branch of the intermediate cutaneous communicates with the femoral branch of the genito-femoral nerve, and frequently pierces the sartorius.

The *medial cutaneous nerve of the thigh* lies at first on the lateral side of the femoral artery, but at the apex of the femoral triangle it crosses in front of the artery and divides into an anterior and a posterior branch. Before dividing, the nerve gives off a few filaments which pierce the fascia lata to supply the skin of the medial side of the thigh, in the neighbourhood of the long saphenous vein; one of these filaments emerges through the saphenous opening (fossa ovalis), and a second becomes subcutaneous about the middle of the thigh. The *anterior branch* runs downwards on the sartorius, perforates the fascia lata at the junction of the middle with the lower one-third of the thigh, and divides into two branches: one supplies

the skin as low as the medial side of the knee; the other crosses to the lateral side of the patella, communicating in its course with the infrapatellar branch of the saphenous nerve. The *posterior branch* descends along the posterior border of the sartorius to the knee, where it pierces the fascia lata, communicates with the saphenous nerve, and gives off several cutaneous branches. It then passes down to supply the skin of the medial side of the leg. Beneath the fascia lata, at the lower border of the adductor longus, it joins to form a plexiform network (*subsartorial plexus*) with branches of the saphenous and obturator nerves. When the communicating branch from the obturator nerve is large and continued to the skin of the leg, the posterior branch of the medial cutaneous is small, and terminates in the plexus, occasionally giving off a few cutaneous filaments.

The *nerve to the sartorius* arises in common with the intermediate cutaneous nerve of the thigh.

The posterior division of the femoral nerve gives off the saphenous nerve, and supplies muscular branches to the quadriceps femoris, and articular branches to the knee-joint.

The **saphenous nerve** (fig. 984) is the largest cutaneous branch of the femoral nerve. It descends on the lateral side of the femoral artery and enters the subsartorial canal (adductor canal) (p. 786) where it crosses the artery obliquely from its lateral to its medial side. At the lower end of the canal it quits the artery, and emerges through the aponeurotic covering of the canal, accompanied by the saphenous branch of the descending genicular artery (arteria genu suprema). It descends vertically along the medial side of the knee behind the sartorius, pierces the fascia lata between the tendons of the sartorius and gracilis, and becomes subcutaneous. It then passes down the tibial side of the leg accompanied by the long saphenous vein, descends along the medial border of the tibia, and, at the lower third of the leg, divides into two branches: one continues its course along the margin of the tibia, and ends at the ankle; the other passes in front of the ankle, and is distributed to the skin on the medial side of the foot as far as the ball of the great toe, communicating with the medial branch of the musculocutaneous nerve (superficial peroneal nerve).

About the middle of the thigh, the saphenous nerve gives a branch to join the subsartorial plexus.

After leaving the adductor canal it gives off an *infrapatellar branch* (fig. 982), which pierces the sartorius and fascia lata, and is distributed to the skin in front of the patella. Above the knee this nerve unites with the medial and intermediate cutaneous nerves of the thigh; below the knee, with other branches of the saphenous nerve; and, on the lateral side of the joint, with branches of the lateral cutaneous nerve of the thigh, forming a plexiform network, termed the *patellar plexus*. The infrapatellar branch is occasionally small.

The *muscular branches* of the posterior division of the femoral nerve supply the quadriceps femoris. The branch to the rectus femoris enters the upper part of the deep surface of the muscle, and supplies a filament to the hip-joint. The branch to the vastus lateralis, of large size, accompanies the descending branch of the lateral circumflex femoral artery to the lower part of the muscle, and sends an articular filament to the knee-joint. The branch to the vastus medialis descends through the upper part of the subsartorial canal, on the lateral side of the saphenous nerve and the femoral vessels. It enters the muscle about its middle, and gives off a filament, which can usually be traced downwards on the surface of the muscle, to the knee-joint. The branches to the vastus intermedius, two or three in number, enter the anterior surface of the muscle about the middle of the thigh; a filament from one of these descends through the muscle to the articularis genu and the knee-joint.

THE ANTERIOR PRIMARY RAMI OF THE SACRAL AND COCCYGEAL NERVES

The **anterior primary rami of the sacral and coccygeal nerves** form the sacral and coccygeal plexuses. Those of the upper four sacral nerves enter the pelvis through the anterior sacral foramina, that of the fifth between the sacrum

and coccyx, while that of the coccygeal nerve curves forwards below the rudimentary transverse process of the first piece of the coccyx. The first and second sacral nerves are large ; the third, fourth and fifth diminish progressively ; the coccygeal nerve is the smallest. Each of these nerves receives a *grey ramus communicans* from the corresponding ganglion of the sympathetic trunk. *Visceral efferent fibres* arise from the second, third and fourth sacral nerves, but they do not join the neighbouring sympathetic ganglia ; they are named the *pelvic splanchnic nerves*, and consist of parasympathetic fibres which pass directly to minute ganglia on the walls of the pelvic viscera (p. 1152).

The Sacral Plexus

The **sacral plexus** (fig. 985) is formed by the lumbosacral trunk, the anterior primary rami of the first, second and third sacral nerves, and part of the anterior primary ramus of the fourth sacral nerve.

The lumbosacral trunk comprises a part of the anterior primary ramus of the fourth lumbar nerve, and the whole of the anterior primary ramus of the fifth lumbar nerve ; it appears at the medial margin of the psoas major and descends over the pelvic brim and in front of the sacro-iliac joint to join the first sacral nerve.

The anterior primary ramus of the fourth sacral nerve divides into an upper and a lower branch ; the upper branch enters the sacral plexus ; the lower descends to assist in forming the coccygeal plexus.

Relations.—The sacral plexus lies on the posterior wall of the pelvic cavity in front of the piriformis (fig. 986), and behind the internal iliac (hypogastric) vessels, the ureter and the pelvic colon, on the left side, and the terminal coils of the ileum, on the right side. The superior gluteal vessels run between the lumbosacral trunk and the first sacral nerve, or between the first and second sacral nerves, and the inferior gluteal vessels between the anterior primary rami of the first and second, or second and third, sacral nerves.

The nerves forming the sacral plexus converge towards the lower part of the greater sciatic foramen, and unite to form a flattened band, from the anterior and posterior surfaces of which several branches arise ; the band itself is continued as the sciatic nerve.

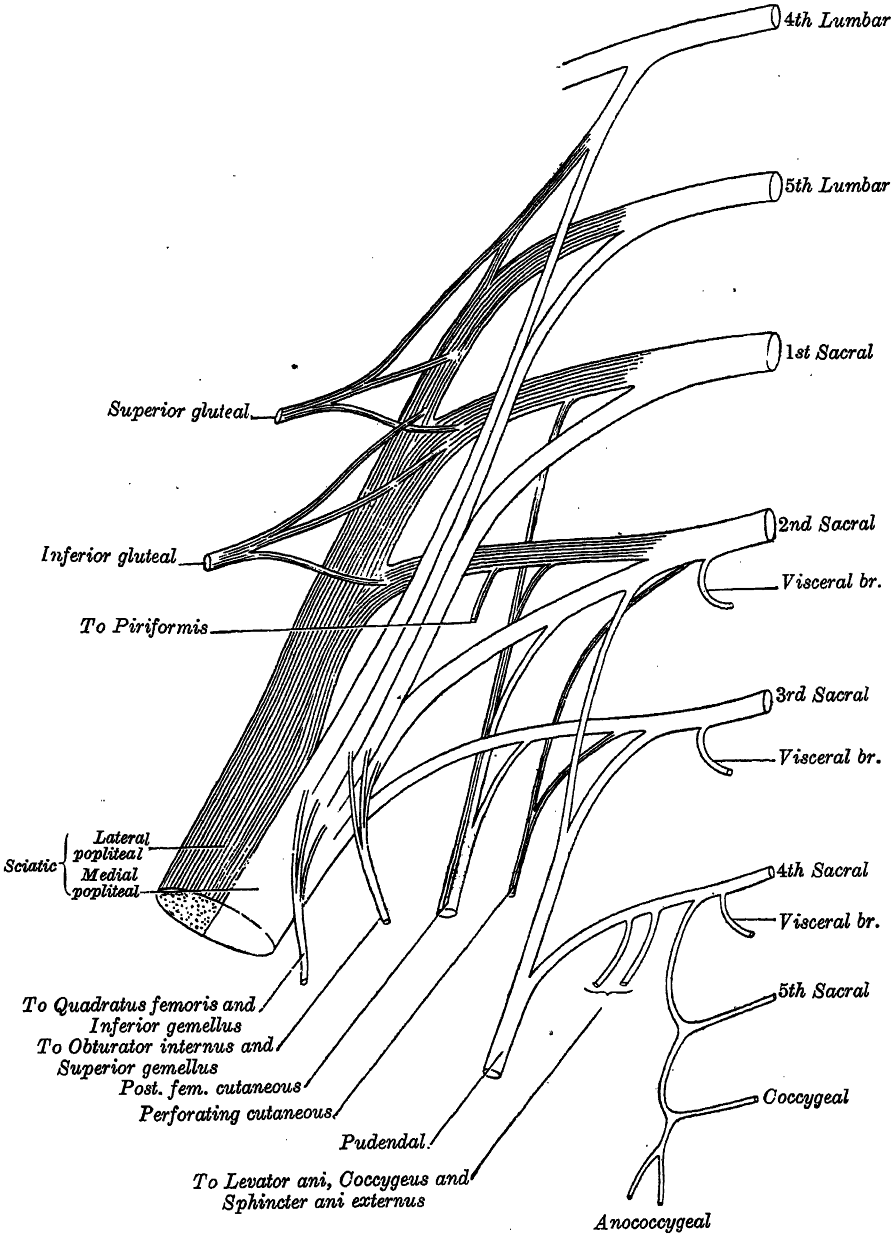
The nerves entering the plexus split into ventral and dorsal divisions ; the nerves arising from these divisions are as follows :

	Ventral divisions.	Dorsal divisions.
Nerve to quadratus femoris and gemellus inferior	4, 5 L., 1 S.	
Nerve to obturator internus and gemellus superior	5 L., 1, 2 S.	
Nerve to piriformis		(1) 2 S.
Superior gluteal		4, 5 L., 1 S.
Inferior gluteal		5 L., 1, 2 S.
Posterior femoral cutaneous	2, 3 S.	1, 2 S.
Sciatic: Medial popliteal	4, 5 L., 1, 2, 3 S.	
Sciatic: Lateral popliteal		4, 5 L., 1, 2 S.
Perforating cutaneous		2, 3 S.
Pudendal	2, 3, 4 S.	
Nerves to levator ani, coccygeus and sphincter ani externus	4 S.	
Pelvic splanchnics	2, 3, (4) S.	

The **nerve to the quadratus femoris and gemellus inferior** arises from the ventral branches of the anterior primary rami of the fourth and fifth lumbar and first sacral nerves (fig. 985) ; it leaves the pelvis through the greater sciatic foramen below the piriformis, and, running down on the ischium deep to the sciatic nerve, the gemelli and the tendon of the obturator internus, supplies a twig to the gemellus inferior, and enters the anterior surface of the quadratus femoris ; it gives an articular branch to the hip-joint.

The **nerve to the obturator internus and gemellus superior** arises from the ventral branches of the anterior primary rami of the fifth lumbar and first and second sacral nerves (fig. 985). It leaves the pelvis through the greater sciatic foramen below the piriformis, and gives a branch which enters the upper part

FIG. 985.—A plan of the sacral and coccygeal plexuses.

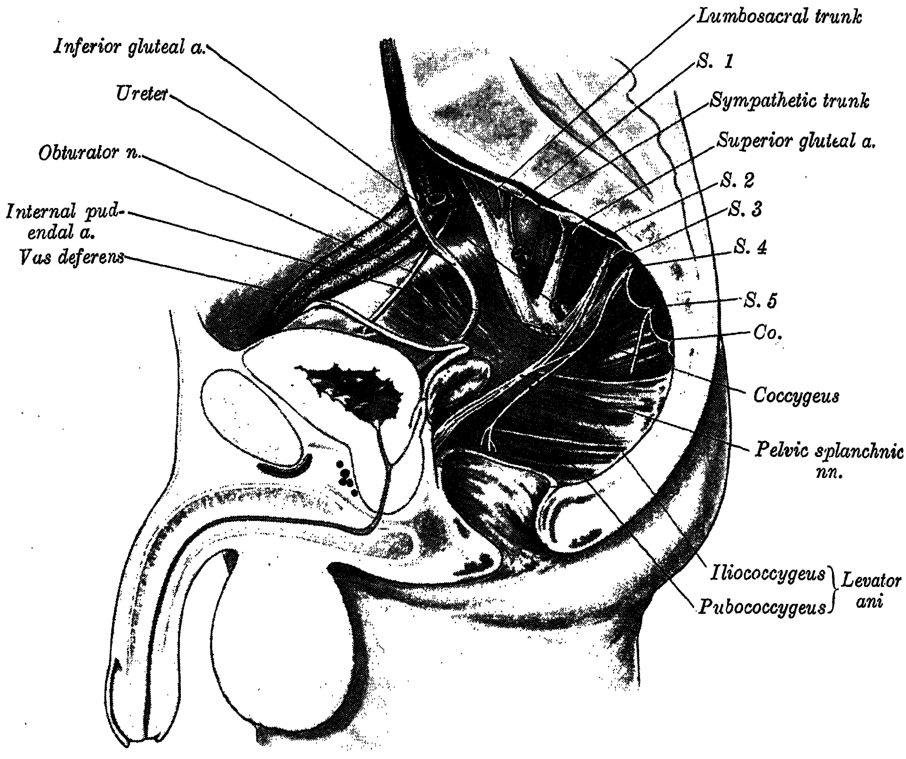


of the posterior surface of the gemellus superior. It then crosses the ischial spine on the lateral side of the internal pudendal vessels, re-enters the pelvis through the lesser sciatic foramen, and pierces the pelvic surface of the obturator internus.

The **nerve to the piriformis** arises usually from the dorsal branches of the anterior primary rami of the first and second sacral nerves; it enters the anterior surface of the muscle.

The **superior gluteal nerve** arises from the dorsal branches of the anterior primary rami of the fourth and fifth lumbar and first sacral nerves (fig. 985) : it leaves the pelvis through the greater sciatic foramen above the piriformis, accompanied by the superior gluteal vessels, and divides into a superior and an inferior branch. The *superior* branch accompanies the upper branch of the deep division of the superior gluteal artery and ends in the gluteus minimus. The *inferior* branch runs with the lower branch of the deep division of the superior gluteal artery across the gluteus minimus ; it gives twigs to the gluteus medius and gluteus minimus, and ends in the tensor fasciæ latæ.

Fig. 986.—A dissection of the side wall of the pelvis, showing the sacral and coccygeal plexuses.



The **inferior gluteal nerve** arises from the dorsal branches of the anterior primary rami of the fifth lumbar and first and second sacral nerves : it leaves the pelvis through the greater sciatic foramen, below the piriformis, and divides into branches which enter the deep surface of the gluteus maximus.

The **posterior cutaneous nerve of the thigh** arises from the dorsal branches of the anterior primary rami of the first and second, and from the ventral branches of the anterior primary rami of the second and third, sacral nerves (fig. 985), and issues from the pelvis through the greater sciatic foramen below the piriformis. It then descends under cover of the gluteus maximus with the inferior gluteal artery, lying posterior or medial to the sciatic nerve. It runs down the back of the thigh superficial to the long head of the biceps femoris, and deep to the fascia lata ; at the back of the knee it pierces the deep fascia and accompanies the short saphenous vein as far as the middle of the calf of the leg, its terminal twigs communicating with the sural nerve.

Its branches are all cutaneous, and are distributed to the gluteal region, the perineum, and the back of the thigh and leg.

The *gluteal branches*, three or four in number, turn upwards round the lower border of the gluteus maximus, and supply the skin covering the lower and lateral part of that muscle.

Fig. 987.—The cutaneous nerves of the right lower limb. Posterior surface.

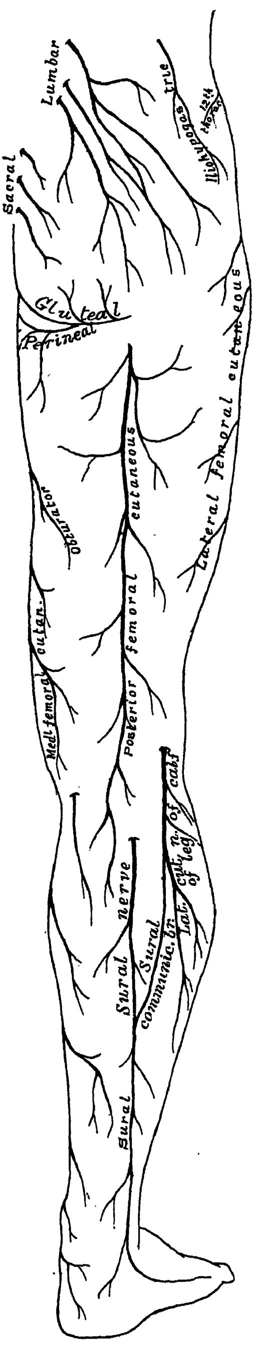


Fig. 988.—A diagram showing the segmental distribution of the cutaneous nerves of the right lower limb. Posterior surface.

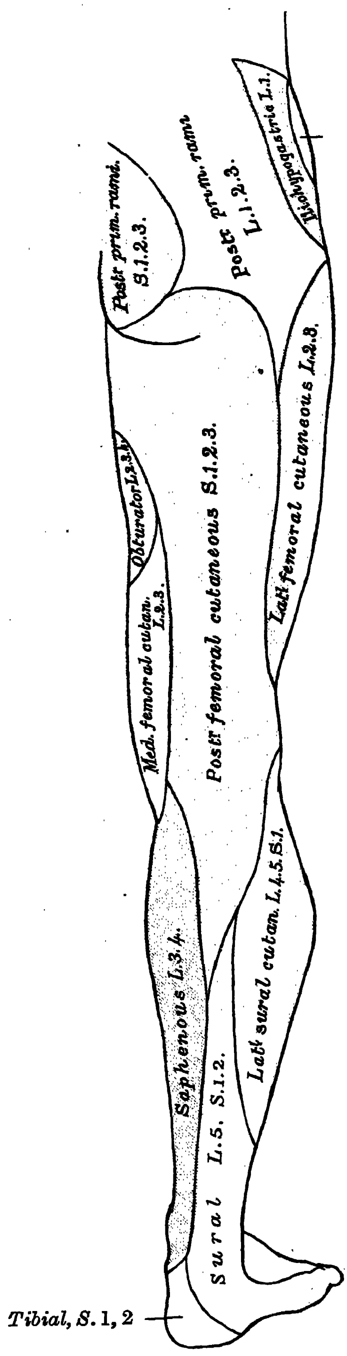
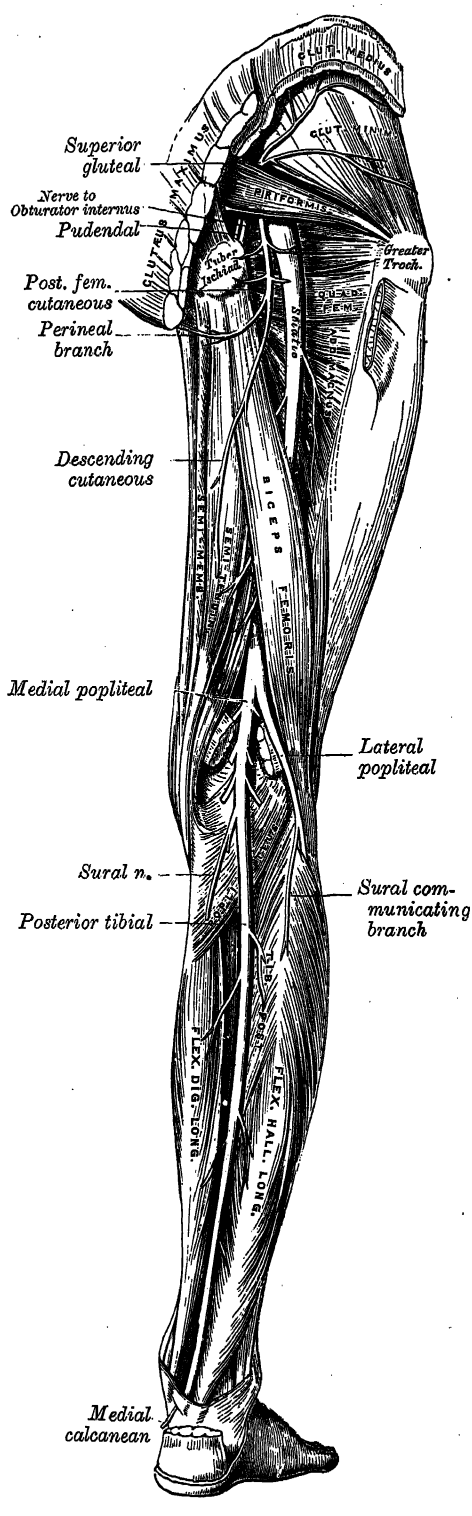


FIG. 989.—The nerves of the right lower limb.* Posterior aspect.



The *perineal branch* distributes twigs to the skin at the upper and medial side of the thigh, and then curves forwards across the origin of the hamstrings, below the ischial tuberosity; it pierces the fascia lata, and runs beneath the superficial fascia of the perineum to the skin of the scrotum in the male, and of the labium majus in the female, joining with the inferior hæmorrhoidal and the scrotal branches of the perineal nerve.

The *branches to the back of the thigh and leg* consist of numerous filaments derived from both sides of the nerve, and distributed to the skin covering the back and medial side of the thigh, the popliteal fossa and the upper part of the back of the leg (fig. 987).

The **sciatic nerve** (figs. 985, 989) is the largest nerve in the body and at its commencement it measures 2 cm. in breadth. It is the continuation of the flattened band of the sacral plexus. It passes out of the pelvis through the greater sciatic foramen, below the piriformis muscle, descends between the greater trochanter of the femur and the tuberosity of the ischium, and along the back of the thigh to about its lower one-third, where it divides into two large branches, named the medial popliteal (tibial) and lateral popliteal (common peroneal) nerves. This division may take place at any point between the sacral plexus and the lower one-third of the thigh, and in all cases the independence of the two nerves can be shown by dissection. When the division occurs at the plexus, the lateral popliteal nerve usually pierces the piriformis. The nerve also gives off articular and muscular branches.

In the upper part of its course the nerve is placed under cover of the gluteus maximus, and rests first upon the posterior surface of the ischium, the nerve to the quadratus femoris intervening; it then crosses the obturator internus and gemelli, and passes on to the quadratus femoris, by which it is separated from the obturator externus and the hip-joint; it is accompanied on its medial side by the posterior

* N.B.—In this diagram the gluteus maximus, the gluteus medius and the superficial muscles of the calf of the leg have been removed.

cutaneous nerve of the thigh and the inferior gluteal artery. Lower down it lies upon the adductor magnus, and is crossed obliquely by the long head of the biceps femoris.

The *articular branches* of the sciatic nerve arise from the upper part of the nerve, and supply the hip-joint by perforating the posterior part of its capsule; they are sometimes derived from the sacral plexus.

The *muscular branches* of the sciatic nerve are distributed to the biceps femoris, semitendinosus, semimembranosus and adductor magnus; the branches to the semimembranosus and adductor magnus arise by a common trunk. The nerve to the short head of the biceps femoris comes from the lateral popliteal (common peroneal) part, while the other muscular branches arise from the medial popliteal (tibial portion), of the sciatic nerve.

The **medial popliteal nerve** (tibial nerve) (fig. 989), the larger, terminal branch of the sciatic nerve, arises from the ventral branches of the anterior primary rami of the fourth and fifth lumbar and first, second and third sacral nerves. It descends along the back of the thigh and through the middle of the popliteal fossa, to the lower part of the popliteus muscle, whence it passes with the popliteal artery deep to the arch of soleus, and is thereafter continued into the leg as the *posterior tibial nerve*. In the thigh it is overlapped by the hamstring muscles above, but it becomes more superficial in the popliteal fossa, where it lies lateral to, and some distance from, the popliteal vessels; it is superficial to these vessels opposite the knee-joint and then crosses to the medial side of the popliteal artery. In the lower part of the popliteal fossa, the nerve is covered by the contiguous margins of the two heads of the gastrocnemius.

The branches of this nerve are: articular, muscular and sural.

Articular branches, usually three in number, supply the knee-joint; one branch accompanies the superior, and another the inferior, medial genicular artery; the third branch runs with the middle genicular artery.

The *muscular branches* arise from the nerve as it lies between the two heads of the gastrocnemius muscle; they supply that muscle, as well as the plantaris, soleus and popliteus. The nerve to the soleus enters the superficial surface of the muscle. The branch for the popliteus descends, crossing the popliteal vessels obliquely, and turns round the lower border of the muscle to be distributed to its deep surface; it supplies small branches to the tibialis posterior, an articular twig to the upper tibiofibular joint, a medullary branch to the tibia, and an interosseous branch, which descends close to the fibula, and can be traced to the inferior tibiofibular joint.

The *sural nerve* (medial sural cutaneous nerve) descends between the two heads of the gastrocnemius, and, piercing the deep fascia about the middle of the back of the leg, is joined by the sural communicating branch of the lateral popliteal nerve (fig. 987). It then passes downwards near the lateral margin of the tendo calcaneus, and close to the short saphenous vein, to the interval between the lateral malleolus and the calcaneum; it supplies the skin of the lateral and posterior part of the lower one-third of the leg. It runs forwards below the lateral malleolus, and is continued along the lateral side of the foot and little toe, communicating on the dorsum of the foot with the musculocutaneous (superficial peroneal) nerve. In the leg, its branches communicate with those of the posterior cutaneous nerve of the thigh.

The **posterior tibial nerve** begins at the lower border of the popliteus, where it is directly continuous with the medial popliteal nerve; it descends in company with the posterior tibial vessels to the interval between the heel and the medial malleolus, where it ends under cover of the flexor retinaculum (laciniate ligament) by dividing into the medial and lateral plantar nerves. In the upper part of its course it is covered posteriorly by the superficial muscles of the calf, but in the lower third of the leg it is covered only by the skin and fasciæ, although it is overlapped sometimes by the medial edge of the flexor hallucis longus muscle. Above, it lies on the medial side of the posterior tibial vessels, but it soon crosses behind them and descends to its point of bifurcation along their lateral side. In most of its course it lies on the tibialis posterior, but in the lower part of the leg it comes into relation with the posterior surface of the tibia.

The branches of this nerve are articular, muscular, medial calcanean and medial and lateral plantar.

The *articular branch* arises from the posterior tibial nerve just above its terminal bifurcation, and supplies the ankle-joint.

The *muscular branches* arise either independently or by a common trunk. They supply the soleus, on its deep surface, the tibialis posterior, the flexor digitorum longus and the flexor hallucis longus ; the branch to the last muscle accompanies the peroneal vessels.

The *medial calcanean branches* perforate the flexor retinaculum (laciniate ligament), and supply the skin of the heel and medial side of the sole of the foot.

FIG. 990.—The plantar nerves of the right foot.

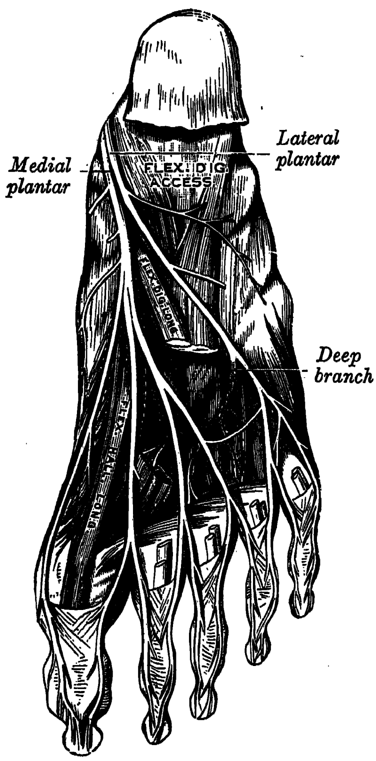
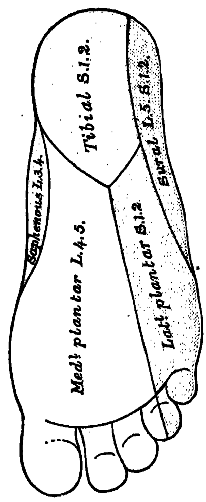


FIG. 991.—A diagram showing the segmental distribution of the cutaneous nerves of the sole of the right foot.



The **medial plantar nerve** (fig. 990), the larger of the two terminal divisions of the posterior tibial nerve, accompanies the medial plantar artery and lies on the lateral side of the vessel. From its origin under cover of the flexor retinaculum it passes deep to the abductor hallucis, and, appearing between this muscle and the flexor digitorum brevis, gives off a digital nerve to the medial side of the great toe and finally divides opposite the bases of the metatarsal bones into three plantar digital nerves.

Branches.—Cutaneous branches pierce the plantar aponeurosis between the abductor hallucis and the flexor digitorum brevis and are distributed to the skin of the sole of the foot.

Muscular branches supply the abductor hallucis, the flexor digitorum brevis, the flexor hallucis brevis and the first lumbrical muscle ; those for the abductor hallucis and flexor digitorum brevis arise from the trunk of the nerve near its origin and enter the deep surfaces of the muscles ; the branch for the flexor hallucis brevis springs from the digital nerve to the medial side of the great toe, and that for the first lumbrical muscle from the first plantar digital nerve.

Articular branches supply the articulations of the tarsus and metatarsus.

The *digital nerve of the great toe* supplies the flexor hallucis brevis and the skin on the medial side of the great toe.

The *three plantar digital nerves* pass between the divisions of the plantar aponeurosis, and each splits into two branches. Those of the first plantar digital nerve supply the adjacent sides of the great and second toes ; those of the second, the adjacent sides of the second and third toes ; and those of the third, the adjacent sides of the third and fourth toes. The third plantar digital nerve receives a communicating branch from the lateral plantar nerve ; the first gives a twig to the first lumbrical muscle. Each digital branch gives off cutaneous and articular filaments and opposite the distal phalanx sends upwards a dorsal branch, which supplies the structures around the nail, the continuation of the nerve being distributed to the ball of the toe. *It will be observed that the digital branches of the medial plantar nerve are similar in their distribution to those of the median nerve in the hand. The muscles supplied by the two nerves also correspond closely.* In the hand, the median nerve supplies the abductor and the flexor pollicis brevis, the opponens pollicis and the first and second lumbricals. The opponens muscle is absent in the foot, but the abductor and short flexor of the great toe and the first lumbrical are all supplied by the medial plantar nerve. As the flexor digitorum brevis corresponds to the flexor digitorum sublimis (median nerve) of the upper limb, the only real difference consists in the innervation of the second lumbrical muscle.

The lateral plantar nerve (fig. 992) supplies the skin of the fifth toe and lateral half of the fourth, as well as most of the deep muscles, *its distribution being similar to that of the ulnar nerve in the hand.* It passes forwards obliquely in company with the lateral plantar artery, which lies on the lateral side of the nerve, and reaches the lateral side of the foot near the tubercle of the fifth metatarsal bone. It passes between the flexor digitorum brevis and the flexor digitorum accessorius (quadratus plantæ), and ends in the interval between the former muscle and the abductor digiti minimi by dividing into a superficial and a deep branch. Before its division, it supplies the flexor digitorum accessorius and abductor digiti minimi.

The *superficial branch* splits into two plantar digital nerves ; of these the lateral supplies the lateral side of the little toe, the flexor digiti minimi brevis, and the two interosseous muscles of the fourth intermetatarsal space ; the medial communicates with the third plantar digital branch of the medial plantar nerve and divides into two branches which supply the adjoining sides of the fourth and fifth toes.

The *deep branch* accompanies the lateral plantar artery on the deep surface of the tendons of the flexor muscles and the adductor hallucis, and supplies the second, third and fourth lumbricals, the adductor hallucis and all the interosseous muscles (except those of the fourth intermetatarsal space). The nerves to the second and third lumbricals pass forwards deep to the transverse head of the adductor hallucis, and then pass downwards and backwards across its anterior (or distal) border to reach the muscles (fig. 992).

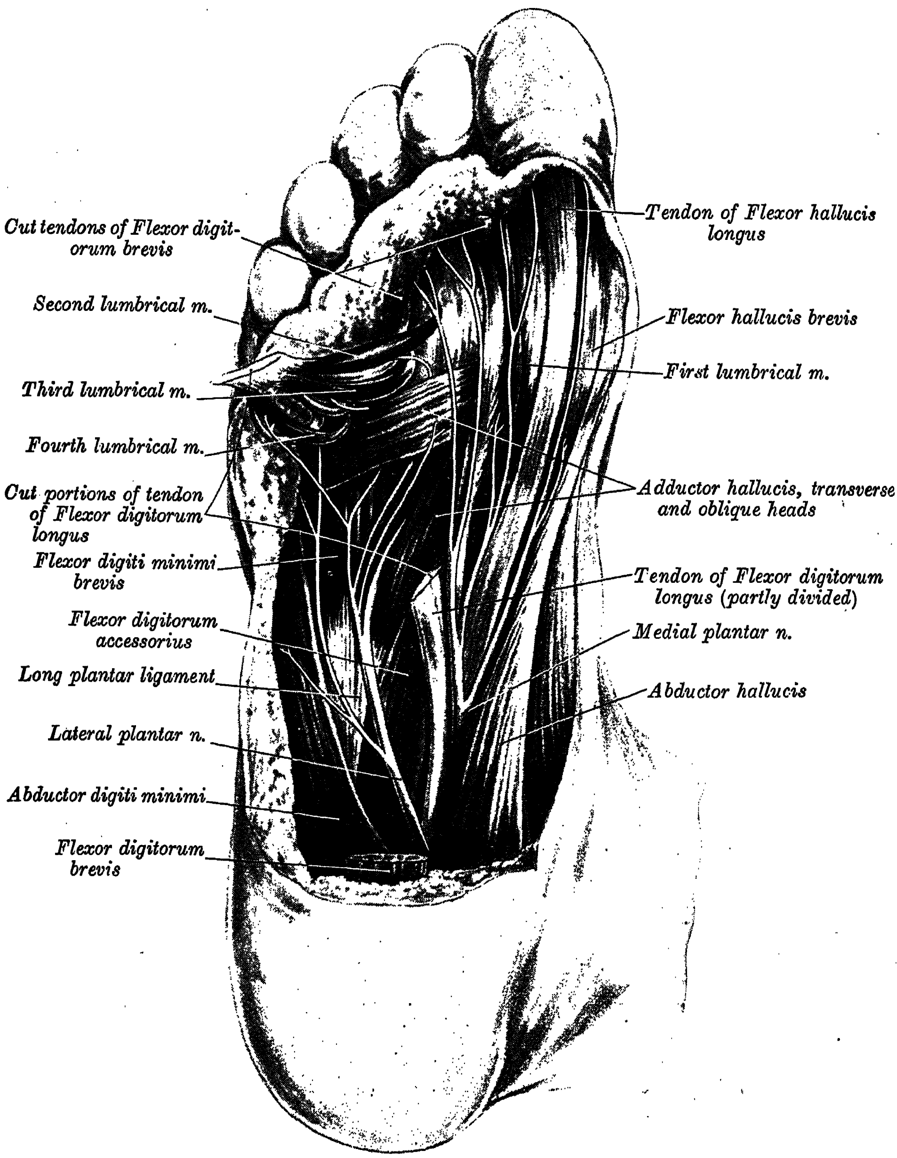
The lateral popliteal nerve (common peroneal nerve) (fig. 989), about one-half the size of the medial popliteal, is derived from the dorsal branches of the anterior primary rami of the fourth and fifth lumbar and the first and second sacral nerves. It descends obliquely along the lateral side of the popliteal fossa to the head of the fibula, close to the medial margin of the biceps femoris muscle. It lies between the tendon of the biceps femoris and the lateral head of the gastrocnemius muscle, winds round the lateral surface of the neck of the fibula deep to the peroneus longus, and divides into the musculocutaneous (superficial peroneal) and anterior tibial (deep peroneal) nerves. Previous to its division it gives off articular and cutaneous branches.

The *articular branches* are three in number ; two of these accompany the superior and inferior lateral genicular arteries to the knee ; the upper one occasionally arises from the trunk of the sciatic nerve. The third, named the recurrent articular nerve, is given off at the point of division of the lateral popliteal nerve ; it ascends with the anterior recurrent tibial artery through the tibialis anterior to the front of the knee-joint.

The *cutaneous branches*, two in number, frequently spring from a common trunk ; they are the lateral cutaneous nerve of the calf of the leg and the sural communicating branch.

The *lateral cutaneous nerve of the calf of the leg* supplies the skin on the anterior, posterior and lateral surfaces of the proximal part of the leg. The *sural communicating branch* arises near the head of the fibula, runs obliquely across the lateral head of the gastrocnemius to the middle of the leg, and joins with the sural nerve (p. 1123). It occasionally descends as a separate branch as far as the heel.

FIG. 992.—A dissection of the lateral and medial plantar nerves of the right foot.



Most of the flexor digitorum brevis has been removed. The flexor digitorum longus has been partially divided and its distal end has been turned forwards together with the second, third and fourth lumbrical muscles.

The **anterior tibial nerve** (deep peroneal nerve) (fig. 984) begins at the bifurcation of the lateral popliteal nerve, between the fibula and proximal part of the peroneus longus, passes obliquely forwards deep to the extensor digitorum longus to the front of the interosseous membrane, where it comes into relation with the anterior tibial artery in the upper one-third of the leg ; it then descends with the artery to the front of the ankle-joint, where it divides into lateral and

medial terminal branches. It lies at first on the lateral side of the anterior tibial artery, then in front of it, and again on its lateral side at the ankle-joint.

In the leg, the anterior tibial nerve supplies *muscular branches* to the tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius, and an *articular branch* to the ankle-joint.

The *lateral terminal branch* of the anterior tibial nerve passes across the tarsus, deep to the extensor digitorum brevis, and having become enlarged, like the posterior interosseous nerve at the wrist, supplies the extensor digitorum brevis. From the enlargement three minute *interosseous branches* are given off which supply the tarsal joints, and the metatarsophalangeal joints of the second, third, and fourth toes. The first of these sends a filament to the second dorsal interosseous muscle.

The *medial terminal branch* of the anterior tibial nerve runs forwards on the dorsum of the foot, and lies on the lateral side of the dorsalis pedis artery. At the first interosseous space it communicates with the medial branch of the musculocutaneous (superficial peroneal) nerve, and divides into two dorsal digital nerves, which supply the adjacent sides of the great and second toes. Before it divides it gives off an *interosseous branch* which supplies the metatarsophalangeal joint of the great toe and sends a filament to the first dorsal interosseous muscle.

The **musculocutaneous nerve** (superficial peroneal nerve) (fig. 984) begins at the bifurcation of the lateral popliteal nerve and lies at first between the peroneus longus and the peroneus brevis. It then passes forwards between the peronei and the extensor digitorum longus, pierces the deep fascia at the lower one-third of the leg, and divides into a medial and a lateral branch. In its course between the muscles, it gives off muscular branches to the peroneus longus and peroneus brevis, and filaments to the skin of the lower part of the leg.

The *medial branch* passes in front of the ankle-joint, and divides into two dorsal digital nerves, one of which supplies the medial side of the great toe, the other, the adjacent sides of the second and third toes. It communicates with the saphenous nerve and with the anterior tibial nerve (fig. 982).

The *lateral branch*, the smaller, passes along the lateral part of the dorsum of the foot, and divides into dorsal digital branches, which supply the contiguous sides of the third and fourth, and of the fourth and fifth toes. It also supplies the skin of the lateral side of the ankle, and communicates with the sural nerve (fig. 982).

The branches of the musculocutaneous nerve supply the skin of the dorsal surfaces of all the toes excepting the lateral side of the little toe and the adjoining sides of the great and second toes, the former being supplied by the sural nerve, and the latter by the medial terminal branch of the anterior tibial nerve. Frequently some of the lateral branches of the musculocutaneous are absent, and their places are then taken by branches of the sural nerve.

The **perforating cutaneous nerve** usually arises from the posterior aspects of the second and third sacral nerves. It pierces the lower part of the sacrotuberous ligament, and, winding round the inferior border of the gluteus maximus, supplies the skin covering the medial and lower parts of that muscle.

The perforating cutaneous nerve may arise from the pudendal nerve or it may be absent; in the latter case its place may be taken by a branch from the posterior cutaneous nerve of the thigh or by a branch from the third and fourth, or fourth and fifth, sacral nerves.

The **pudendal nerve** derives its fibres from the second, third and fourth sacral nerves (fig. 985). Passing between the piriformis and the coccygeus, it leaves the pelvis through the lower part of the greater sciatic foramen and enters the buttock, where it crosses the spine of the ischium on the medial side of the pudendal artery. It accompanies this artery through the lesser sciatic foramen into the pudendal canal (p. 573) on the lateral wall of the ischiorectal fossa; in the posterior part of this canal it gives off the inferior hæmorrhoidal, and then divides into the perineal nerve, and the dorsal nerve of the penis or clitoris.

The *inferior hæmorrhoidal nerve* occasionally arises directly from the sacral plexus; it pierces the medial wall of the pudendal canal, crosses the ischiorectal fossa with the inferior rectal vessels, and is distributed to the sphincter ani externus and to the skin round the anus. Branches of this nerve commun-

icate with the perineal branch of the posterior cutaneous nerve of the thigh and with the scrotal nerve.

The *perineal nerve*, the inferior and larger terminal branch of the pudendal nerve, runs forwards below the internal pudendal artery. It accompanies the perineal artery and divides into scrotal (or labial) and muscular branches.

The *scrotal branches* are two, a medial and a lateral. They pierce, or pass superficial to, the perineal membrane (inferior fascia of the urogenital diaphragm), and run forwards along the lateral part of the urethral triangle in company with the scrotal branches of the perineal artery; they are distributed to the skin of the scrotum, and communicate with the perineal branch of the posterior cutaneous nerve of the thigh. In the female the corresponding nerves (*labial branches*) supply the labium majus.

The muscular branches are distributed to the transversus perinei superficialis, bulbocavernosus, ischiocavernosus, transversus perinei profundus and sphincter urethræ. A branch, termed the *nerve to the urethral bulb*, is given off from the nerve to the bulbocavernosus; it pierces this muscle, and supplies the corpus spongiosum penis (corpus cavernosum urethræ), ending in the mucous membrane of the urethra.

The *dorsal nerve of the penis* runs forwards above the internal pudendal artery along the ramus of the ischium, and accompanies the artery along the margin of the inferior ramus of the pubis, on the deep surface of the perineal membrane. It pierces the membrane, and gives a branch to the corpus cavernosum penis. It then passes forwards, in company with the dorsal artery of the penis, between the layers of the suspensory ligament, to the dorsum of the penis, and ends in the glans penis. In the female the corresponding nerve (*dorsal nerve of the clitoris*) is very small, and supplies the clitoris.

The **visceral branches** arise from the second, third and fourth sacral nerves, and are distributed to the pelvic viscera. They are termed the *pelvic splanchnic nerves* (p. 1138).

The **muscular branches** are derived from the fourth sacral, and supply the levator ani, coccygeus and sphincter ani externus. The branches to the levator ani and coccygeus enter their pelvic surfaces; that to the sphincter ani externus (perineal branch of fourth sacral nerve) reaches the ischiorectal fossa by piercing the coccygeus or by passing between it and the levator ani. Cutaneous filaments from this branch supply the skin between the anus and the coccyx.

The coccygeal plexus.—The coccygeal plexus is formed by a small descending branch from the anterior primary ramus of the fourth sacral nerve, and the anterior primary rami of the fifth sacral and coccygeal nerves. The anterior primary ramus of the fifth sacral nerve emerges from the sacral hiatus and turns forwards round the lateral margin of the sacrum below the cornu. It pierces the coccygeus muscle to gain its pelvic surface and is then joined by a descending filament from the fourth sacral nerve. The small trunk so formed descends on the pelvic surface of the coccygeus and unites with the minute anterior primary ramus of the coccygeal nerve, which descends from the sacral hiatus, turns round the lateral margin of the coccyx and pierces the coccygeus to gain the pelvis. This small trunk constitutes the *coccygeal plexus*. The anococcygeal nerves arise from this plexus, and consist of a few fine filaments which pierce the sacrotuberous ligament and supply the skin in the region of the coccyx.

The Morphology of the Spinal Nerves and the Limb Plexuses

A typical spinal nerve divides shortly after its origin into a posterior and an anterior primary ramus. The posterior primary ramus passes dorsally and penetrates the dorsal muscle mass. It divides into medial and lateral branches, one of which terminates, as a rule, in the skin of the dorsal aspect of the trunk.

The anterior primary ramus proceeds laterally and forwards into the body wall. In the first part of its course it establishes connexions with the sympathetic system and then, as it courses forwards in the substance of the somatopleure, it gives off a lateral branch which passes towards the surface and divides into anterior and posterior branches. The nerve is then continued onwards and terminates not far from the median plane by distributing its anterior terminal branches to the skin of the body wall.

The spinal nerves which conform to the primitive arrangement in their behaviour are the nerves of those segments which have retained to a large extent their metameric characters, viz. T. 2-L. 1. In the cervical and lumbosacral regions the primitive metameric arrangement has disappeared to a large extent and the conditions have been profoundly altered by the development of the limbs. With the disappearance of metamerism the derivatives of adjoining myotomes fuse with one another, and the muscles so formed retain in whole or in part their primitive segmental innervation. The musculature of the limbs develops *in situ* in the mesodermal core of the limb bud, but phylogenetically it may be regarded as a derivative of the myotomes of the segments which are concerned in the formation of the limb. The fusion of derivatives from adjoining myotomes is indicated in the composite origin of the nerves to most of the limb muscles.

The typical spinal nerves are distributed according to a very definite plan. The posterior primary ramus passes backwards and downwards lateral to the articular processes and divides into a medial and a lateral branch which penetrate the deep muscles of the back. Both branches innervate the muscles amongst which they lie, and either the one or the other becomes superficial and supplies a band of skin extending from the posterior median line to the scapular line.

The anterior primary ramus is connected to the corresponding ganglion on the sympathetic trunk by both a white and a grey ramus communicans. After innervating the subvertebral muscles, it passes round the body wall supplying branches to the lateral muscles of the trunk, and in the neighbourhood of the midaxillary line gives off a lateral branch which pierces the overlying muscles and divides into an anterior and a posterior division for the supply of the skin. The main trunk is continued forwards in the body wall and, after supplying the ventral muscles, distributes its terminal branches to the skin.

The behaviour of the anterior primary rami of the spinal nerves of the segments which have lost their obvious metamerism is greatly modified, and the initial modification is seen in the manner in which adjoining nerves unite to form the cervical, brachial, lumbosacral and coccygeal plexuses.

The *cervical plexus*.—The cutaneous branches of this plexus are homologous with the anterior terminal and the lateral branches of the typical spinal nerves. The anterior cutaneous nerve of the neck and the medial supraclavicular nerves represent the anterior terminal branches ; the lesser occipital and the lateral supraclavicular represent the lateral branches, while the great auricular and the intermediate supraclavicular probably represent elements of both branches.

The *brachial plexus*.—In the formation of the brachial and lumbosacral plexuses the division of the constituent nerves of the plexus into anterior or ventral and posterior or dorsal branches is characteristic. This arrangement is obvious in the brachial plexus, where the posterior branches of the three constituent trunks unite to form the posterior cord, and it conforms to the differentiation of the primitive musculature of the limb into a ventral or flexor and a dorsal or extensor group.

It has been urged that the dorsal branches correspond to the lateral branches of the typical spinal nerves, and that the ventral branches represent the anterior portions of these nerves and their anterior terminal branches. On the other hand, the position of the developing limb-bud on the ventrilateral aspect of the trunk and the behaviour of the first and second thoracic nerves provide considerable support for the view that the constituent nerves of the great limb-plexuses represent only the lateral branches of the typical spinal nerves. The second thoracic nerve sends its lateral cutaneous branch into the upper limb as the intercostobrachial nerve, and the size of this nerve varies inversely with the size of the direct contribution which the second thoracic nerve makes to the brachial plexus. Otherwise the second thoracic behaves like a typical spinal nerve. The first thoracic nerve sends a large contribution to the brachial plexus, and this is clearly homologous with the lateral branch. The remainder of the nerve, despite its small size, behaves in a typical manner, although its fine anterior cutaneous branch is often awanting, and, when present, only supplies a limited area of skin.

The *lumbosacral plexus*.—The division of the constituent nerves of the lumbar and sacral plexuses into anterior or ventral and posterior or dorsal divisions is not so obvious as the corresponding division in the brachial plexus, but it can be demonstrated anatomically that the obturator and the medial popliteal (tibial) nerves arise from ventral and the femoral and lateral popliteal (peroneal) nerves from dorsal divisions. The lateral branches of the twelfth thoracic and first lumbar nerves are drawn down over the iliac crest to assist in the innervation of the skin of the buttock, but otherwise these nerves behave as typical spinal nerves. The second lumbar nerve behaves in a manner which renders its interpretation difficult, since it not only gives a substantial contribution to the lumbar plexus but also possesses both an anterior terminal branch, the genital branch of the genitofemoral nerve, and a lateral cutaneous offset, represented by the lateral cutaneous nerve of the thigh and the femoral branch of the genitofemoral nerve. The anterior terminal portions of the third, fourth and fifth lumbar and the first sacral nerves are suppressed, but the corresponding portions of the second and third sacral nerves supply the skin, etc., of the perineum.

The Distribution of the Spinal Nerves to the Skin of the Trunk and Limbs

The cutaneous branches of the typical spinal nerves supply consecutive bands of skin which slope downwards as they are traced round the body from the dorsal to the ventral median line. The upper part of each band receives additional innervation from the nerve of the zone above and its lower part from the nerve of the zone below. Modifications of this arrangement are found in the areas supplied by the cervical, brachial and lumbosacral plexuses.

The first cervical nerve gives off no cutaneous branches. The second cervical nerve usually distributes its cutaneous offsets to the skin of the head, from the vertex backwards to the neighbourhood of the superior nuchal line, the cranial surface and the posterior part of the lateral surface of the auricle, the skin over the angle of the mandible and below the chin (fig. 949). The third cervical nerve supplies a very oblique band of skin, commencing behind over the back of the scalp and the upper part of the back of the neck and passing forwards and downwards across the side of the neck. The area increases in extent as it is traced forwards, and in the ventral median line extends from the hyoid bone down to the level of first rib. The fourth cervical nerve supplies the upper half or more of the back of the neck, and the area widens as it is traced downwards and forwards round the side of the neck to the anterior aspect of the trunk. It supplies the skin over the clavicle and first intercostal space, as well as over the acromion and the upper part of the deltoid muscle.

Each of these three areas is overlapped by the succeeding area, but the amount of overlapping is slight and is greater where the posterior primary rami are involved.

The cutaneous distribution of the nerves of the brachial plexus becomes intelligible only when reference is made to an early stage in the development of the upper limb. In a human embryo of the fourth week the upper limb is represented by a small, somewhat flattened elevation on the ventrilateral aspect of the trunk opposite to the lower four cervical and the first thoracic segments. The ectoderm covering it is directly continuous with the ectoderm of the trunk and draws its nerve supply from the nerves of the corresponding segments. The limb-bud possesses ventral and dorsal surfaces and preaxial, or cephalic, and postaxial, or caudal, borders. The fifth cervical nerve supplies a strip on each surface immediately adjoining the preaxial border, and the first thoracic nerve has a corresponding distribution along the postaxial border. The intervening nerves supply corresponding, parallel strips of skin on both the ventral and dorsal surfaces (fig. 132). As the limb elongates the central nerves of the plexus become buried in its proximal part and reach the skin only in its distal part, and the nerves of the adjoining segments (C. 4 and T. 2) become drawn in to supply the skin at the root of the limb (fig. 975). The preaxial border becomes the lateral aspect and the postaxial border the medial aspect of the limb (p. 101). The highest nerves of the brachial plexus therefore supply

the skin over the lateral aspect of arm and forearm, and the lowest nerves the skin over their medial aspects. Owing to the fact that the central nerves of the plexus are buried in the proximal part of the limb, immediately adjoining areas of skin are innervated by the nerves of widely separated segments (fig. 973), and it is to be remembered that the areas supplied by such nerves do not overlap one another.

On the anterior surface of the upper limb the lateral aspect is supplied by the fifth and sixth cervical nerves and the medial aspect by the eighth cervical and the first and second thoracic nerves. The seventh cervical nerve does not reach the skin until it gains the hand. In the proximal part of the limb the sixth and eighth cervical nerves are also buried, and on the front of the trunk adjoining the limb none of the nerves of the plexus, with the occasional exception of the first thoracic, reach the skin.

The *ventral axial line* is drawn from the median plane laterally across the trunk and the front of the shoulder and is continued down the front of the limb to the wrist. It passes between the areas supplied by spinal nerves which are separated by one or more segments.

The *dorsal axial line* occupies a corresponding position on the dorsal aspect of the limb. It does not, however, continue beyond the elbow, for branches of the seventh cervical nerve, contained in the posterior cutaneous nerve of the forearm, reach the skin over the proximal part of the forearm.

The *skin of the trunk* is supplied by the spinal nerves T. 2 to L. 1, inclusive, and by the sacral nerves, with the exception of the first, and by the coccygeal nerve. These nerves supply consecutive curved bands of skin, of which the upper are almost horizontal while the lower are disposed very obliquely. The upper half of each band receives additional supply from the nerve above and the lower half from the nerve below, so that no appreciable loss of sensibility follows the section of any typical spinal nerve. It is convenient to remember that the band which includes the subcostal angle is supplied by the seventh thoracic nerve and that the umbilicus lies in the upper part of the band supplied by the tenth thoracic nerve.

The areas supplied by the posterior primary rami of these nerves are limited laterally by the dorsilateral line, which commences above on the back of the head and runs downwards and laterally to the medial end of the acromion. It is then continued downwards to the posterior aspect of the greater trochanter of the femur where it curves medially to the coccyx. The cutaneous strips supplied by the posterior primary rami do not correspond exactly to the strips supplied by the anterior primary rami, for they differ both in their breadth and in their position.

On the upper part of the anterior aspect of the thorax the third and fourth cervical areas adjoin the first and second thoracic areas (fig. 978), owing to the fact that the intervening nerves have been drawn off to supply the upper limb, and a similar but less extensive gap is found on the posterior aspect of the trunk.

A corresponding arrangement is found in the lower part of the trunk, but it is not so obvious owing to the approximation of the lower limbs to one another. The first lumbar area adjoins the second sacral area at the root of the penis and scrotum, for the intervening nerves have been drawn off to supply the lower limb.

The *skin of the lower limb* is innervated by the nerves of the segments from which it is derived, viz. L. 2-S. 2. The arrangement originally is precisely similar to the arrangement in the upper limb, but its identification in the adult has been rendered difficult on account of the torsion of the lower limb in the early stages of its development (p. 101). As a result the pre- and post-axial borders cannot be recognised so easily as in the upper limb, and the ventral and dorsal axial lines curve round the limb as they descend.

The preaxial border commences above on the middle of the front of the thigh and runs down to the knee. It then curves medially as it descends to the medial malleolus to gain the medial side of the foot and the hallux. The postaxial border commences above in the gluteal region and descends to the popliteal fossa. It then inclines laterally as it descends to the lateral malleolus to gain the lateral side of the foot. The *ventral* and *dorsal axial lines* necessarily

exhibit a corresponding obliquity. The ventral axial line commences above at the medial end of the inguinal ligament and runs down the medial side of the thigh to the knee. It then winds round the medial side of the calf and terminates on the back of the leg at the point where the fifth lumbar nerve reaches the skin (fig. 988). The dorsal axial line commences in the lateral part of the gluteal region and descends on the posterolateral aspect of the thigh to the knee. It then curves round the lateral side of the leg and terminates on the anterior aspect, where the fibres of the fifth lumbar nerve reach the skin.

The Distribution of the Spinal Nerves to the Muscles of the Body

Each spinal nerve originally supplies the musculature derived from the myotome of the same segment. In cases where the derivatives of any one myotome persist as separate entities, they retain their original nerve-supply, but when derivatives of adjoining myotomes fuse, the resultant muscle does not necessarily retain its supply from each of the corresponding nerves, although it may and frequently does retain them all. Since the limb muscles develop *in situ* in the mesodermal core of the developing limb, it is impossible to identify the individual segments from which any muscle is derived by the study of its mode of development. The union of the individual spinal nerves and their branches in the brachial and lumbosacral plexuses renders impossible the identification by anatomical methods of the root value of the individual motor nerves. Recourse, therefore, must be had to clinical observations and experimental work on monkeys. The results obtained by these methods are not entirely satisfactory, and although there is substantial agreement with regard to certain muscles, there is considerable divergence of opinion with regard to many others, as may be seen from the accompanying table, in which italics are used to denote the muscles concerning which there is lack of agreement.

Applied Anatomy.—The lumbar plexus passes through the psoas major, and therefore in psoas abscess any or all of its branches may be irritated, causing severe pain in the part to which the irritated nerves are distributed. The genitofemoral nerve is the one which is most frequently implicated. This nerve is also of importance as it is concerned in one of the principal superficial reflexes employed in the investigation of diseases of the spinal cord. If the skin over the medial side of the thigh just below the inguinal ligament (the part supplied by the femoral branch of the genitofemoral nerve) be tickled in the male child, the testis will be retracted, through the action of the cremaster muscle, which is supplied by the genital branch of the genitofemoral nerve. The same result may sometimes be noticed in adults, and can almost always be produced by severe stimulation. This reflex shows that the portion of the spinal cord from which the first and second lumbar nerves are derived is in a normal condition.

The femoral nerve is in danger of being injured in fractures of the true pelvis, since the fracture most commonly takes place through the superior ramus of the pubis, at or near the point where this nerve crosses the bone. When this nerve is paralysed the patient is unable to flex his hip completely, on account of the paralysis of the iliacus; or to extend the knee on the thigh, on account of paralysis of the quadriceps femoris; there is complete paralysis of the sartorius, and usually of the pectineus. There is loss of sensation down the front and medial side of the thigh, except in that part supplied by the genitofemoral and ilio-inguinal nerves. There is also loss of sensation down the medial side of the leg and foot as far as the ball of the great toe.

The obturator nerve is rarely paralysed alone, but occasionally in association with the femoral. The principal interest attached to it is in connexion with its supply to the knee, pain in the knee being symptomatic of many diseases in which the trunk of this nerve, or one of its branches, is irritated. Thus it is well known that in the earlier stages of hip-joint disease the patient may not always complain of pain in that articulation, but on the medial side of the knee, or in the knee-joint itself, both of these articulations being supplied by the obturator nerve, the final distribution of the nerve being to the knee-joint. Again, the same thing may occur in sacro-iliac disease; or in cases of pathological growth of the ovary or tubal inflammation; or in cancer of the pelvic colon; and even in cases where masses of hardened fæces are impacted in this portion of the gut, pain is complained of in the knee. Finally, pain in the knee forms an important diagnostic sign in obturator hernia. When the obturator nerve is paralysed the patient is unable to press his knees together or to cross one leg over the other on account of paralysis of the adductor muscles. Lateral rotation of the thigh is impaired from paralysis of the obturator externus. Sometimes there is loss of sensation in the upper half of the medial side of the leg.

TABLE OF THE MUSCLES SUPPLIED BY THE INDIVIDUAL SPINAL NERVES

N.B.—The root value of the innervation of muscles printed in heavy type may be regarded as reliable. The root value of the innervation of muscles printed in italics is very doubtful.

NERVE	ANTERIOR PRIMARY RAMUS	POSTERIOR PRIMARY RAMUS
C. 1	Rectus lateralis, rectus anterior, longus capitis, geniohyoid, infrahyoid muscles.	*Rectus capitis posterior major*, rectus capitis posterior minor, *obliquus superior*, obliquus inferior, semispinalis capitis.
C. 2	Longus capitis, longus cervicis, *scalenus medius*, sternomastoid, *trapezius*, geniohyoid, infrahyoid muscles.	Obliquus inferior, semispinalis capitis, splenius, longissimus capitis.
C. 3	Longus capitis, longus cervicis, *scalenus anterior*, scalenus medius, infrahyoid muscles, levator scapulæ, trapezius, *sternomastoid, diaphragm.*	Semispinalis capitis, splenius and deep muscles of back of neck.
C. 4	Longus capitis, longus cervicis, *scalenus anterior*, scalenus medius, levator scapulæ, *trapezius*, **diaphragm.**	Semispinalis capitis, splenius and deep muscles of back of neck.
C. 5	Longus cervicis, scalenes, *levator scapulæ*, **rhomboids, serratus anterior, subclavius, supraspinatus, infraspinatus**, teres minor, *subscapularis*, **deltoid**, *pectoralis major*, **biceps, brachialis**, *brachioradialis, supinator, diaphragm.*	Deep muscles of back of neck.
C. 6	Longus cervicis, *scalenus anterior*, scalenus medius, scalenus posterior, **serratus anterior**, latissimus dorsi, *infraspinatus, teres minor*, subscapularis, **teres major**, *deltoid*, **pectoralis major, biceps, brachialis, pronator teres, flexor carpi radialis**, *brachioradialis, supinator*, **extensor carpi radialis longus et brevis**, pronator quadratus, flexor pollicis longus, *abductor, opponens and flexor brevis pollicis.*	Deep muscles of back of neck.
C. 7	*Longus cervicis*, scalenus medius, *scalenus posterior*, **serratus anterior, pectoralis major**, pectoralis minor, latissimus dorsi, *teres major*, **coracobrachialis, triceps**, anconeus, flexor digitorum sublimis, *flexor digitorum profundus, flexor pollicis longus*, pronator quadratus, radial extensors of wrist, **extensors of digits, extensor carpi ulnaris**, *abductor, opponens* and *flexor brevis pollicis.*	Deep muscles of back of neck.
C. 8	*Longus cervicis, scalenus medius, scalenus posterior*, **pectoralis major, pectoralis minor, latissimus dorsi, triceps**, anconeus, **flexors of digits, palmaris longus, flexor carpi ulnaris**, adductor pollicis, interossei, lumbricales, abductor, opponens and flexor digiti minimi.	Deep muscles of back.
T. 1	*Pectoralis major, pectoralis minor, flexors of digits, flexor carpi ulnaris, palmaris longus*, **small muscles of hand,*** 1st intercostals, serratus posterior superior, 1st levator costæ.	,, ,,
T. 2	2nd intercostals, 2nd levator costæ, serratus posterior superior, *sternocostalis.*	,, ,,
T. 3	3rd intercostals, 3rd levator costæ, serratus posterior superior, sternocostalis.	,, ,,
T. 4	4th intercostals, 4th levator costæ, serratus posterior superior, sternocostalis.	,, ,,
T. 5	5th intercostals, 5th levator costæ, sternocostalis.	,, ,,
T. 6	6th intercostals, 6th levator costæ, rectus abdominis, *external oblique.*	,, ,,
T. 7	7th intercostals, 7th levator costæ, subcostal, external oblique, internal oblique, transversus abdominis, rectus abdominis.	,, ,,
T. 8	8th intercostals, 8th levator costæ, subcostal, external oblique, internal oblique, transversus abdominis, rectus abdominis.	,, ,,
T. 9	9th intercostals, 9th levator costæ, subcostal, external oblique, internal oblique, transversus abdominis, rectus abdominis, serratus posterior inferior.	,, ,,

*** Clinical observations show that section of T. 1 is always associated with complete paralysis of the small muscles of the hand.**

TABLE OF THE MUSCLES SUPPLIED BY THE INDIVIDUAL SPINAL NERVES—*Continued*

NERVE	ANTERIOR PRIMARY RAMUS	POSTERIOR PRIMARY RAMUS
T. 10	10th intercostals, 10th levator costæ, subcostal, external oblique, internal oblique, transversus abdominis, rectus abdominis, serratus posterior inferior.	Deep muscles of back.
T. 11	11th intercostals, 11th levator costæ, subcostal, external oblique, internal oblique, transversus abdominis, rectus abdominis, serratus posterior inferior.	„ „
T. 12	12th levator costæ, *quadratus lumborum,* external oblique, internal oblique, transversus abdominis, rectus abdominis, pyramidalis.	„ „
L. 1	Quadratus lumborum, internal oblique, transversus abdominis, cremaster.	„ „
L. 2	*Quadratus lumborum, cremaster,* psoas major, *iliacus,* pectineus, sartorius, adductor longus, adductor brevis, *gracilis, vastus medialis.*	„ „
L. 3	Psoas major, obturator externus, adductors, gracilis, iliacus, pectineus, sartorius, quadriceps (all heads).	„ „
L. 4	*Psoas major,* obturator externus, *adductor brevis,* adductor magnus, gracilis, rectus femoris, vastus lateralis, vastus intermedius, *vastus medialis,* gluteus medius, gluteus minimus, tensor fasciæ latæ, quadratus femoris, gemellus inferior, *obturator internus,* semimembranosus, *semitendinosus, plantaris, popliteus,* tibialis anterior, extensor hallucis longus, extensor digitorum longus et brevis, peroneus tertius, *peroneus longus, peroneus brevis.*	„ „
L. 5	*Adductor magnus,* gluteus maximus, medius and minimus, tensor fasciæ latæ, quadratus femoris, obturator internus, gemelli, semimembranosus, semitendinosus, biceps (short head), all muscles of leg (except gastrocnemius), extensor digitorum brevis, abductor hallucis, flexor hallucis brevis, flexor digitorum brevis, 1*st and* 2*nd lumbricals.*	„ „
S. 1	Gluteus maximus, medius and minimus, tensor fasciæ latæ, piriformis, obturator internus, quadratus femoris, gemelli, *semimembranosus,* semitendinosus, biceps, all muscles of leg and foot.	„ „
S. 2	Gluteus maximus, piriformis, obturator internus, gemellus superior, *semitendinosus,* biceps (long head), gastrocnemius, soleus, flexor hallucis longus, flexor digitorum brevis, abductor digiti minimi, flexor brevis digiti minimi, *adductor hallucis,* interossei, lumbricals 3 and 4.	„ „
S. 3	Biceps (long head), ischiocavernosus, bulbocavernosus, transversus perinei.	„ „
S. 4	Ischiocavernosus, bulbocavernosus, transversus perinei, levator ani, coccygeus, sphincter ani externus.	„ „
S. 5	*Levator ani, coccygeus, sphincter ani externus.*	„ „

The sciatic nerve is liable to be pressed upon by various forms of pelvic tumour, giving rise to pain along its trunk, to which the term *sciatica* is applied. Tumours growing from the pelvic viscera, and, sometimes, accumulation of fæces in the rectum, may cause pressure on the nerve inside the pelvis, and give rise to sciatica. Most cases of sciatica, however, are due to neuritis of the sciatic nerve. The inflamed nerve, or any of its branches, is often sensitive to pressure, particularly in certain ‘ tender spots ’ (e.g. near the posterior iliac spine, at the sciatic notch, about the middle of the back of the thigh, in the popliteal fossa, below the head of the fibula, behind the malleoli, or on the dorsum of the foot), and pain is felt whenever extension of the leg is attempted and the nerve is stretched. Paralysis of the sciatic nerve is rarely complete ; when the lesion occurs high up there is palsy of the biceps femoris, semimembranosus and semitendinosus, and of all the muscles below the knee. If the lesion be lower down, there is loss of motion in all the muscles below the knee, and loss of sensation in the same situation, except the upper half of the back of

the leg, which is supplied by the posterior femoral cutaneous, and in the area supplied by the saphenous nerve (p. 1117). Lesions of the lateral popliteal nerve cause paralysis of the tibialis anterior, the peronei, the long extensors of the toes and the short extensor on the dorsum of the foot. ' Foot-drop ' follows, dorsal flexion of the toes and eversion of the foot being impossible. Later on, talipes of the equinovarus type results, due to the contracture of the unopposed posterior crural group of muscles.

Frequently the sciatic nerve has been exposed and stretched, or has been acupunctured, for the relief of sciatica. It can easily be marked out on the surface of the thigh (p. 1470).

The position of the lateral popliteal nerve, close behind the tendon of the biceps femoris, on the lateral side of the popliteal fossa, is of considerable practical importance. Owing to the proximity of the nerve the tenotomy of the biceps tendon should be performed by open operation. Where this nerve winds round the neck of the fibula, it is also liable to be severed accidentally. Section of the nerve results in complete ' foot-drop,' from paralysis of the anterior tibial group of muscles, and inversion of the foot, from the unopposed action of the tibialis posterior, the peronei being paralysed, together with anæsthesia of the parts supplied by the nerve, and the limb frequently becomes blue and cold, and may develop ' trophic ' sores.

THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system comprises the splanchnic or visceral components of the nervous system (p. 882), and its fibres are distributed to the various viscera, glands and blood-vessels and to unstriped muscle in general. We have already seen that the development of a limiting sulcus in the lateral wall of the neural tube is a constant feature throughout the vertebrate series, and that as a result a motor area or basal lamina can be differentiated from a sensory area or alar lamina. Further, the nuclei which arise in the dorsal (or lateral) part of the basal lamina constitute the general visceral efferent column, while those which arise in the adjoining part of the alar lamina constitute the visceral afferent column (fig. 840). Certain of the constituents of the autonomic system are so intimately connected anatomically with the somatic system that they have already been dealt with, but it is necessary to repeat, in part, the descriptions already given to enable the student to obtain a comprehensive survey of the autonomic system as a whole.

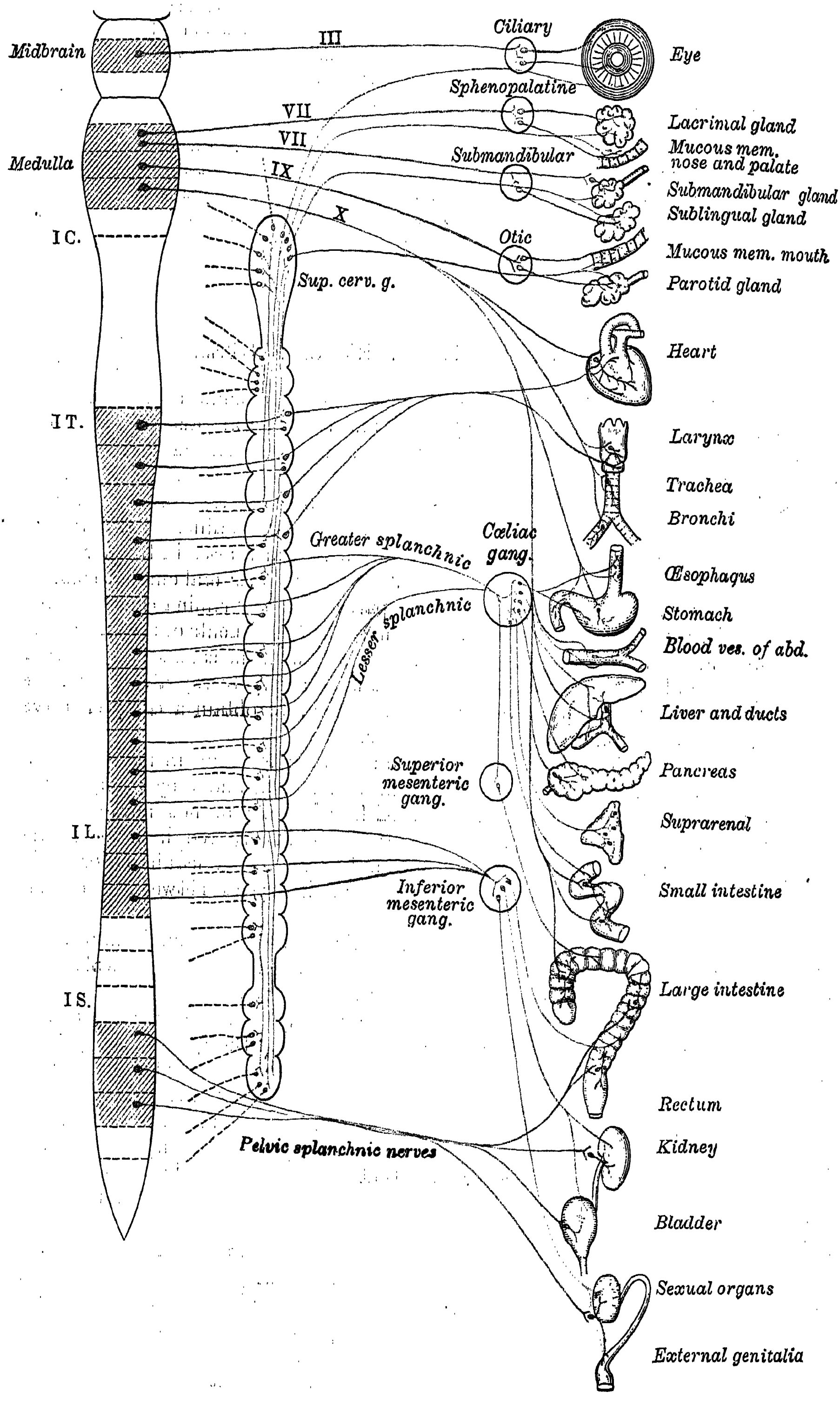
The efferent fibres of the autonomic system take origin in nuclei of cell-groups in the mid-brain, hind-brain and spinal cord, and they emerge from the central nervous system as medullated fibres. They do not, however, pass direct to their distribution. Instead they are interrupted in a peripheral ganglion, and are there relayed to their destination by unmedullated or finely medullated fibres. Two neurones, therefore, are interposed between the central nervous system and the visceral effectors.

No such distinguishing feature marks the afferent autonomic fibres. So far as is known all afferent autonomic fibres are the peripheral branches of nerve-cells placed in the ganglia of the cranial or spinal nerves.

The autonomic nervous system can be subdivided into two more or less complementary parts, viz.: the *parasympathetic* and the *sympathetic systems*, partly on anatomical, partly on physiological and partly on pharmacological grounds. Anatomically it can be demonstrated that most of the viscera of the body receive their nerve-supply from two sources, one source being the parasympathetic system and the other the sympathetic system. Physiologically it can be shown for most of these viscera that the influences of these two systems are antagonistic to one another.* Pharmacologically, it has been found that certain poisons which paralyse the sympathetic nerve endings do not affect the parasympathetic nerves, and *vice versa*. In addition, the sympathetic system comprises two gangliated trunks, together with their communications and their branches of distribution and subsidiary ganglia, so that it constitutes a definite anatomical entity, whereas the parasympathetic system utilises certain of the cranial and certain of the sacral spinal nerves as its pathways and does not lend itself readily for anatomical demonstration.

* For a discussion of the chemical changes involved, see Sir H. H. Dale's Croonian Lecture: " Some chemical factors in the control of the circulation," *Lancet*, 1929.

FIG. 993.—A diagram of the efferent side of the autonomic nervous system. (After Meyer and Gottlieb.) The parasympathetic fibres are represented by *blue*, and the sympathetic fibres, by *red* lines; the interrupted red lines indicate post-ganglionic fibres to the cranial and spinal nerves.



THE PARASYMPATHETIC SYSTEM

The parasympathetic system has a limited origin from the cranial and sacral ends of the central nervous system, but has a very wide field of distribution. It is characteristic of the fibres of this system that they are all relayed in ganglia which are situated peripherally, many of them being small collections of nerve-cells lying in the walls of the viscera themselves and quite invisible to the unaided eye. The parasympathetic fibres are found in (1) the oculomotor, (2) the facial, (3) the glossopharyngeal, (4) the vagus and accessory nerves, and also (5) in the second and third (and fourth) sacral nerves.

(1) The oculomotor parasympathetic fibres take origin in the mid-brain, and it is believed that they are derived from the Edinger-Westphal nucleus (p. 947). The preganglionic fibres travel in the nerve and leave by the branch which it supplies to the inferior oblique muscle to enter the ciliary ganglion. There they are relayed, and the postganglionic fibres leave the ganglion in the short ciliary nerves, which pierce the sclerotic and run fowards in the peri-choroidal space, to be distributed to the ciliary muscle (p. 1170) and the sphincter pupillæ (p. 1171).

(2) The facial nerve contains efferent parasympathetic fibres which arise in the superior salivary nucleus (p. 1059). They travel in the facial nerve, leaving it a little above the stylomastoid foramen in the chorda tympani, which traverses the tympanic cavity and ultimately reaches the lingual nerve. In this way they are conveyed to the submandibular region, where they enter the submandibular (submaxillary) ganglion, in which the secretomotor fibres for the submandibular salivary gland are relayed (*see also* p. 1272). The secretomotor fibres for the sublingual gland are continued forwards in the lingual nerve after they have been relayed in the submandibular ganglion (*see also* p. 1272). Electrical stimulation of the chorda tympani produces dilatation of the vessels of both these salivary glands in addition to a secretomotor effect. In addition, the facial nerve probably contains efferent parasympathetic fibres which are secretomotor to the lacrimal gland. They travel by the nerve of the pterygoid canal and are relayed in the sphenopalatine ganglion.

(3) The glossopharyngeal contains efferent parasympathetic fibres, which are secretomotor to the parotid gland. They arise in the inferior salivary nucleus (p. 1068) and travel in the glossopharyngeal nerve and its tympanic branch (p. 1069). After traversing the tympanic plexus, they enter the lesser superficial petrosal nerve and so reach the otic ganglion. There they are relayed and travel by communicating branches to the auriculotemporal nerve, by which they are conveyed to the parotid gland. Electrical stimulation of the lesser superficial petrosal nerve produces a vasodilator as well as a secretomotor effect.

The glossopharyngeal nerve also contains afferent fibres, which convey general visceral sensibility from the wall of the pharynx, and probably end in the dorsal nucleus of the vagus. The parent cells are situated in the inferior ganglion of the glossopharyngeal nerve. It is doubtful whether these fibres should be included under the parasympathetic system.

(4) The vagus and the cranial part of the accessory nerve contain a very large proportion of parasympathetic fibres. The efferent fibres arise in the dorsal nucleus of the vagus (p. 1069) and travel in the vagus nerve and in its pulmonary, cardiac, œsophageal, gastric, intestinal, etc., branches. They are all relayed in minute ganglia which lie in the walls of the individual viscera. The cardiac nerves are the depressor nerves of the heart. They take part in the formation of the cardiac plexuses (p. 1149) and are then relayed in ganglia which are distributed freely over the surfaces of both atria in the subepicardial tissue. Their terminal fibres are distributed to the atria and the atrioventricular bundle, and it is only through the latter structure that the vagus can exert any control over the ventricular muscle.* According to Woollard,† the smaller branches of the coronary arteries are mainly innervated by the vagus, whereas their larger branches, though possessing a double innervation, obtain their chief

* Cullis, W., and Tribe, E., *Journal of Physiology*, vol. xlvi. 1913.

† H. H. Woollard, *Journal of Anatomy*, vol. lx.

source of supply from the sympathetic system. The *pulmonary branches* are motor to the muscles of the bronchi, which are circularly disposed and are therefore bronchoconstrictors. The *gastric branches* are secretomotor to the glands and motor to the muscular coats of the stomach, but they inhibit the action of the pyloric sphincter. The *intestinal branches* have a corresponding action on the small intestine, being secretomotor to the glands and motor to the muscular coats of the gut, but inhibitory to the ileocolic sphincter. They are distributed through the myenteric (Auerbach's) plexus and the plexus of the submucosa (Meissner's plexus), which are described with the structure of the intestines.

Afferent fibres of the vagus convey general visceral sensibility from the alimentary canal and also, possibly, from the heart, lungs, etc. The parent cells are situated in the inferior ganglion (ganglion nodosum) (p. 1070) and the central branches of their axons terminate in the dorsal nucleus of the vagus. It is doubtful whether these fibres should be included under the parasympathetic system.

(5) The anterior primary rami of the second, third and (fourth) sacral nerves give off visceral branches which pass directly to the pelvic viscera. They constitute the *pelvic splanchnic nerves*, and they unite with branches of the sympathetic pelvic plexuses. Minute ganglia are situated at the points of union and in the walls of the individual viscera. In these ganglia the sacral parasympathetic fibres are relayed.

The pelvic splanchnic nerves supply: (*a*) the rectum, with visceromotor fibres; (*b*) the bladder, with visceromotor, and its sphincter with inhibitory fibres; (*c*) the uterus, with visceromotor fibres; and (*d*) the erectile tissue of the penis or clitoris with vasodilator fibres. In addition, filaments from these nerves are said * to pass upwards through the hypogastric plexus and to be distributed to the colon along all the branches of the inferior mesenteric artery.

Afferent fibres from the pelvic viscera traverse the pelvic splanchnic nerves. Their parent cells are situated in the ganglia on the posterior nerve-roots of the second, third and (fourth) sacral nerves. It is doubtful whether these fibres should be included under the parasympathetic system.

THE SYMPATHETIC SYSTEM

The **sympathetic nervous system,** which is the larger subdivision of the autonomic nervous system, includes the two gangliated sympathetic trunks, their branches, plexuses and subsidiary ganglia. It has a much wider distribution than the parasympathetic system, for it innervates all the sweat glands of the skin, the erector muscles of the hairs and the muscular walls of all the blood-vessels, in addition to the heart, lungs and other viscera. The fibres which it distributes are all derived from the central nervous system, but little is known concerning their central connexions and pathways. There is good ground for believing that in cats a higher sympathetic centre, which can influence heart-rate and control carbohydrate metabolism, exists in the lower part of the lateral wall of the third ventricle.† The fibres which arise in this part of the hypothalamus descend through the brain-stem, where they lie in the dorsal part of the formatio reticularis, and can be traced into the spinal cord. The efferent fibres from the central nervous system arise from the lateral column of the grey substance of the spinal cord and emerge in the anterior nerve-roots of the thoracic and upper lumbar nerves. The limitation of this outflow from the spinal cord to a specific region is remarkable and has not been satisfactorily explained.

The ganglia on the sympathetic trunks are the first part of the system to develop, and they are derived from the primitive spinal ganglia, which originate from the neural crest (p. 108). Originally, therefore, the ganglia on the sympathetic trunk correspond numerically to the ganglia on the posterior nerve-roots of the spinal nerves, but fusion of adjoining ganglia is not uncommon, and in man there are rarely more than twenty-two or twenty-three,

* E. D. Telford and J. S. B. Stopford, *British Medical Journal*, March 31, 1934.

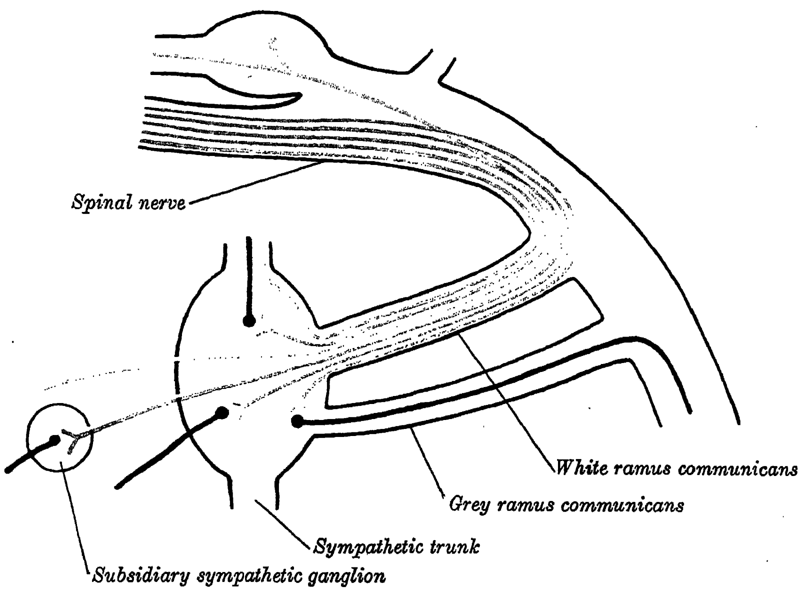
† J. Beattie, G. R. Brow and C. N. H. Long, *Phil. Trans.* B, vol. cvi. 1930.

and there may be fewer discrete ganglia. The subsidiary ganglia of the sympathetic system are derivatives of the ganglia of the trunks.

The efferent fibres from the spinal cord to the sympathetic system are always interrupted in a sympathetic ganglion. It follows that the efferent fibres distributed by the sympathetic system are in every case the axons of nerve-cells situated within a sympathetic ganglion. These fibres can conveniently be differentiated as *preganglionic* and *postganglionic fibres*.

Two varieties of communicating branches connect the ganglia on the sympathetic trunk with the spinal nerves. These are termed *grey* and *white rami communicantes*. At least one *grey ramus communicans* connects each spinal nerve to the corresponding sympathetic ganglion. It conveys postganglionic fibres from the ganglion to the nerve for distribution to the blood-vessels, sweat glands and arrectores pilorum muscles in its area.

FIG. 994.—A scheme to show the destination of the preganglionic fibres of a white ramus communicans. The preganglionic fibres are shown in *red* and the postganglionic fibres in *black*. An afferent sympathetic fibre is shown in *blue*.



One *white ramus communicans* connects each of the thoracic and the first, second and, sometimes, the third lumbar nerves to the corresponding sympathetic ganglion. It conveys efferent preganglionic fibres from the nerve to the ganglion and, in addition, it transmits afferent visceral fibres from the ganglion to the nerve.

The afferent fibres which travel in the sympathetic system are the peripheral branches of unipolar cells situated in the spinal ganglia. They therefore conform to the arrangement already described for the parasympathetic system.

Structure of the sympathetic ganglia.—The constituent nerve-cells of the sympathetic ganglia are surrounded by a nucleated capsule, like the nerve-cells in the spinal ganglia, but unlike them they are usually multipolar. This is not surprising, for the sympathetic cells are stations on an efferent pathway and must be equipped to receive stimuli from more than one source. Examination of the Nissl's bodies has shown that their size and arrangement is sufficiently constant to justify the view that, despite differences in the behaviour and arrangement of their dendrites and axons, all these cells belong to one type.

The dendrites may pierce the capsule and ramify in the intercellular areas, but in many cases they break up within the capsule. These intracapsular plexuses may be situated on one side of the cell, constituting a *glomerulus*, and two or three neighbouring cells may participate in the formation of a glomerulus. The terminals of the preganglionic fibres break up into fine plexuses which

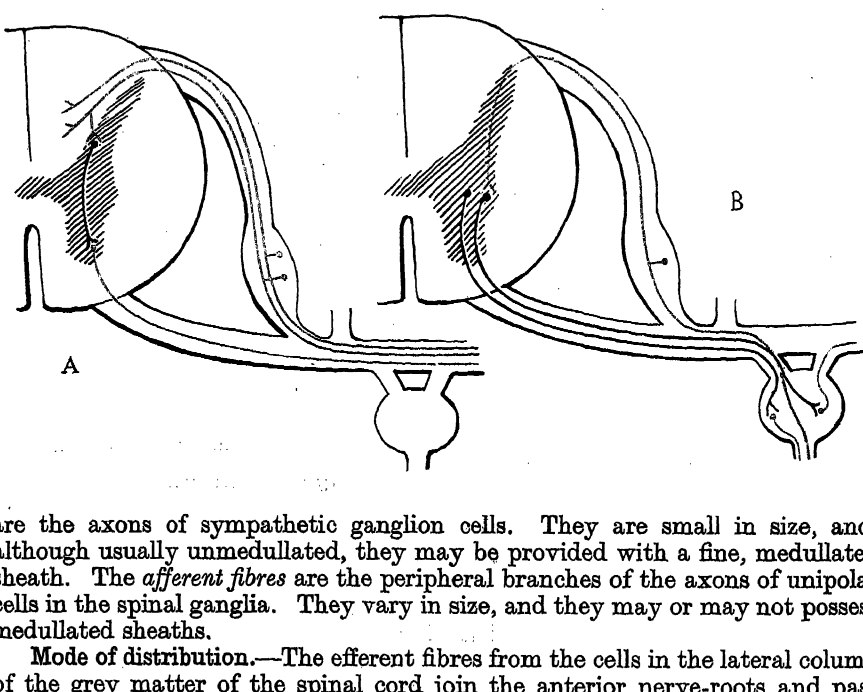
establish synaptic relations with the extracapsular dendrites, or they may form a network which may be either pericapsular or pericellular in position.

The axons of the sympathetic cells are usually fine, unmedullated fibres, but they do occasionally possess a thin sheath of myelin. They are destined either to pass directly to their distribution in one of the medial branches of the sympathetic trunk or to pass by a grey ramus communicans to join a spinal nerve, through which they are distributed. They may, however, ascend to a higher or descend to a lower level in the sympathetic trunk before leaving it. There is no evidence of the existence of any interganglionic association fibres.

The axons of the cells in the subsidiary ganglia pass directly to their distribution.

Structure of the sympathetic nerves.—The *preganglionic fibres* are all derived from the cells in the lateral column of the grey matter of the spinal cord. They are usually small in size and are medullated. The *postganglionic fibres*

Fig. 995.—Diagrams of the central connexions of the somatic fibres (A) and sympathetic fibres (B) of a typical spinal nerve. Afferent fibres, *blue*: connector neurones, *black*: efferent fibres, *red*.



are the axons of sympathetic ganglion cells. They are small in size, and, although usually unmedullated, they may be provided with a fine, medullated sheath. The *afferent fibres* are the peripheral branches of the axons of unipolar cells in the spinal ganglia. They vary in size, and they may or may not possess medullated sheaths.

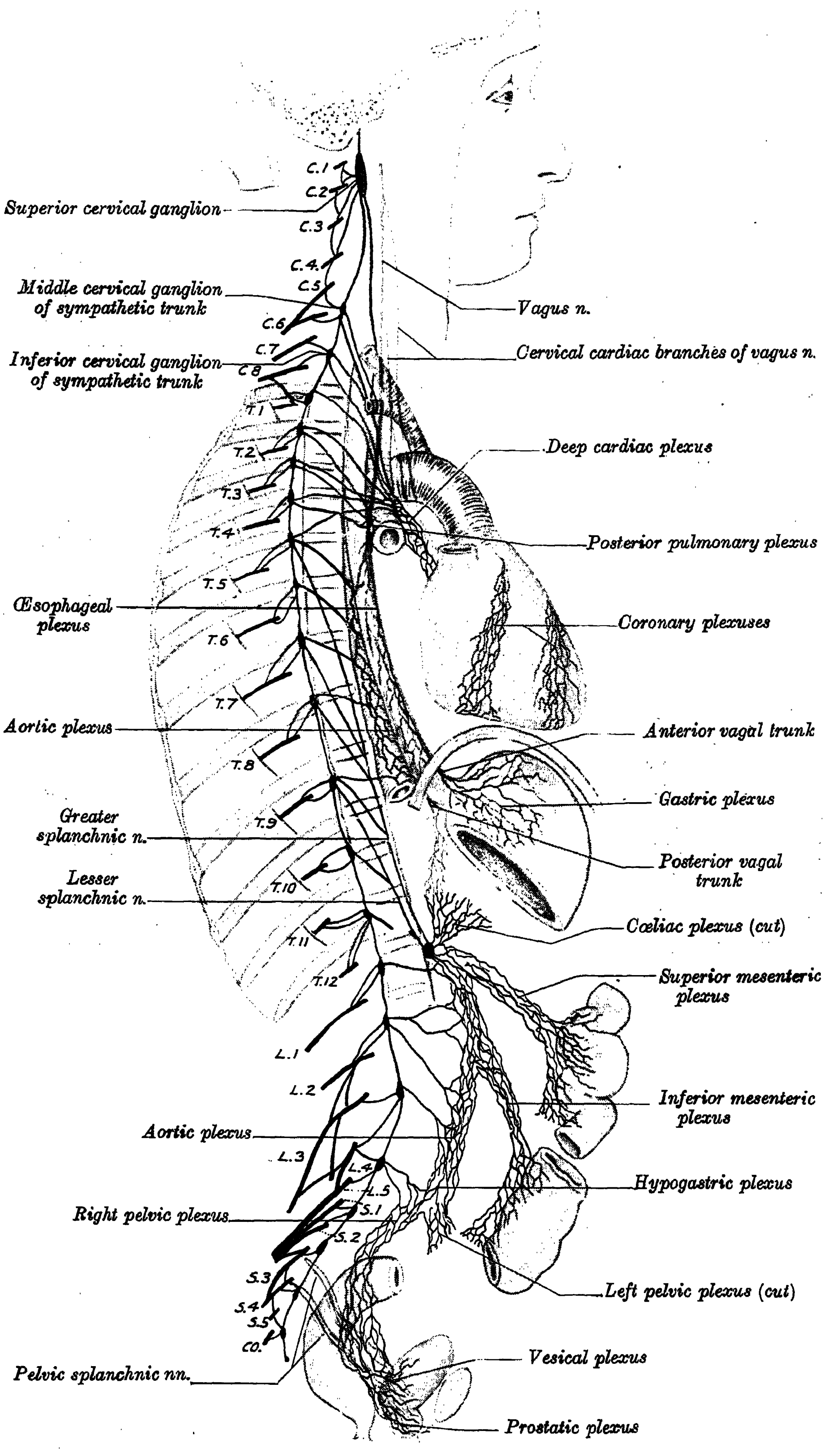
Mode of distribution.—The efferent fibres from the cells in the lateral column of the grey matter of the spinal cord join the anterior nerve-roots and pass into the anterior primary rami of the spinal nerves, T. 1 to L. 2 or 3. They leave the nerves, almost at once, and are conveyed by white rami communicantes to the corresponding ganglia on the sympathetic trunks.

The preganglionic fibres may behave in a number of different ways thereafter. (*a*) They may end in the ganglion by arborising with the dendrites of a ganglion cell ; (*b*) they may pass through the ganglion and ascend to a ganglion at a higher level or descend to one at a lower level before terminating ; (*c*) they may pass through the ganglion without being interrupted, emerge in one of its medial branches and enter a subsidiary ganglion, where they are relayed.

The postganglionic fibres may be arranged in two groups : (*a*) those arising from the ganglia on the sympathetic trunks, and (*b*) those arising from subsidiary ganglia.

(*a*) Postganglionic fibres arising from a ganglion on the sympathetic trunk may reach their distribution in a variety of ways. (1) They may pass back to the corresponding spinal nerve along its grey ramus communicans. Such fibres are distributed by both rami of the spinal nerve to the blood-vessels, sweat-glands, hairs, etc., in its zone of supply. (2) They may pass in a medial branch

FIG. 996.—The right sympathetic trunk and its connexions with the thoracic, abdominal and pelvic plexuses. (After Schwalbe.)



of the ganglion to be distributed to some particular viscus or viscera. (3) They may ascend to a higher level or descend to a lower level before leaving the sympathetic trunk either in one of its medial branches or in a grey ramus communicans. *Postganglionic fibres never travel in a white ramus communicans.*

(*b*) Postganglionic fibres arising from a subsidiary sympathetic ganglion pass direct to their distribution in one of the branches of the ganglion, although they may have to traverse a plexus *en route.*

The afferent fibres are the peripheral branches of unipolar cells in the ganglia on the posterior nerve-roots of the spinal nerves, T. 1 to L. 2 or 3. Very little is known about the end organs with which they are associated. The fibres travel through the sympathetic ganglia without being interrupted and traverse the white rami communicantes to gain the spinal nerve.

The **sympathetic trunks** are two gangliated nerve cords which extend from the base of the skull to the coccyx. In the neck the trunk is placed behind the carotid sheath and in front of the transverse processes of the cervical vertebræ; in the thorax it is placed on the heads of the ribs; in the abdomen on the anterolateral aspect of the bodies of the lumbar vertebræ; and in the pelvis, on the front of the sacrum, medial to the anterior sacral foramina. In front of the coccyx the two trunks meet each other in a terminal ganglion, termed the *ganglion impar.*

In the neck the ganglia are reduced to three in number by the fusion of adjoining ganglia, and from the upper end of the superior ganglion the internal carotid nerve takes origin. This nerve constitutes an upward continuation of the sympathetic trunk, and it accompanies the internal carotid artery through the carotid canal into the skull. In the thorax there are usually eleven ganglia, but the number may be decreased to ten or increased to twelve. There are usually four ganglia in the lumbar region, and four or five in the sacral region.

Functional significance.—Our knowledge of the functional significance of the sympathetic system is very incomplete, and most of the available information concerns the efferent rather than the afferent components.

The fibres which pass to the spinal nerves by the grey rami communicantes supply vasoconstrictor fibres to the blood-vessels, secretomotor fibres to the sweat glands and motor fibres to the arrectores pilorum muscles in the area supplied by the corresponding spinal nerve. In addition, as Boeke has demonstrated, they are distributed to certain of the fibres in voluntary muscles. Hunter and Royle have endeavoured to prove that these sympathetic fibres are concerned with muscle tonus and are responsible for the spasticity of an upper neurone paralysis. The evidence, however, is inconclusive, but their experiments have drawn attention to the fact that, when the sympathetic innervation of voluntary muscle is cut off, the onset of fatigue is abnormally rapid.

The innervation of the individual viscera and of the structures in the head and neck will be dealt with in a subsequent section.

The Cephalic Part of the Sympathetic System

The **cephalic part** of the sympathetic system on each side begins as the **internal carotid nerve,** which is continued upwards from the superior cervical ganglion of the sympathetic trunk. This nerve is soft in texture, and of a reddish colour, and contains postganglionic fibres derived from the cells of the superior cervical ganglion. It ascends by the side of the internal carotid artery, and, entering the carotid canal in the temporal bone, divides into two branches, one of which lies on the lateral and the other on the medial side of the artery.

The *lateral branch,* the larger of the two, gives filaments to the internal carotid artery, and forms the lateral part of the *internal carotid plexus.*

The *medial branch* also supplies filaments to the internal carotid artery, and, continuing onwards, forms the medial part of the internal carotid plexus (cavernous plexus).

The **internal carotid plexus** surrounds the internal carotid artery, and occasionally presents a small gangliform swelling on the under side of the vessel, sometimes termed the *carotid ganglion.* The lateral part of the plexus communicates with the trigeminal (semilunar) and sphenopalatine ganglia, and

with the abducent nerve and the tympanic branch of the glossopharyngeal nerve ; it distributes filaments to the wall of the carotid artery.

The branches communicating with the abducent nerve consist of one or two filaments which join that nerve as it lies upon the lateral side of the internal carotid artery. The communication with the sphenopalatine ganglion is effected by a branch named the *deep petrosal* ; this branch perforates the cartilage filling the foramen lacerum, and joins the greater superficial petrosal nerve to form the nerve of the pterygoid canal, which passes through the pterygoid canal to the sphenopalatine ganglion. The communication with the tympanic branch of the glossopharyngeal nerve is effected by the *superior* and *inferior caroticotympanic nerves*, which traverse the posterior wall of the carotid canal.

The medial part of the internal carotid plexus (cavernous plexus), is situated below and on the medial side of that part of the internal carotid artery which is placed by the side of the sella turcica, in the cavernous sinus. It gives branches to the internal carotid artery, and communicates with the oculomotor, trochlear, ophthalmic and abducent nerves, and with the ciliary ganglion.

The branch to the oculomotor nerve joins that nerve at its point of division ; the branch to the trochlear nerve joins the latter as it lies in the lateral wall of the cavernous sinus ; filaments are connected with the medial side of the ophthalmic nerve ; and one joins the abducent nerve. The filament to the ciliary ganglion arises from the anterior part of the plexus and enters the orbit through the superior orbital fissure ; it may join the ganglion directly ; it may unite with the communicating branch from the nasociliary nerve to the ganglion (p. 1045) ; or, it may travel via the ophthalmic nerve and its nasociliary branch. Its fibres pass through the ciliary ganglion without being interrupted and run in the short ciliary nerves to be distributed to the dilatator pupillæ muscle. The preganglionic fibres concerned leave the spinal cord in T. 1, and pass to the first thoracic sympathetic ganglion. They then ascend in the cervical part of the sympathetic trunk to reach the superior cervical ganglion, where they are relayed.

The terminal filaments from the internal carotid plexus are prolonged as plexuses around the anterior and middle cerebral arteries and the ophthalmic artery : along the anterior and middle cerebral arteries they may be traced to the pia mater ; along the ophthalmic artery they pass into the orbit where they accompany each of the branches of that vessel. The filaments prolonged on the anterior communicating artery connect the sympathetic nerves of the right and left sides.

The Cervical Part of the Sympathetic System

The **cervical part** of each sympathetic trunk consists of three ganglia distinguished, according to their positions, as the superior, middle, and inferior, and connected by intervening cords (fig. 996). This part sends grey rami communicantes to all the cervical spinal nerves,* but receives no white rami communicantes from them ; its spinal fibres are derived from the white rami communicantes of the upper thoracic nerves, and enter the corresponding thoracic ganglia of the sympathetic trunk, through which they ascend into the neck. In their course the grey rami communicantes may pierce the longus capitis or the scalenus anterior muscle.

The **superior cervical ganglion,** the largest of the three, is placed opposite the second and third cervical vertebræ. It is of a reddish-grey colour and usually fusiform in shape, sometimes broad and flattened, and occasionally constricted at intervals ; it is believed to be formed by the coalescence of four ganglia, corresponding with the upper four cervical nerves. It is in relation, in front, with the sheath of the internal carotid artery ; behind, with the longus capitis muscle. The internal carotid nerve (p. 1142) ascends from the upper end of the ganglion into the cranial cavity ; the lower end of the ganglion is united by the connecting trunk with the middle cervical ganglion.

Its branches may be divided into lateral, medial and anterior.

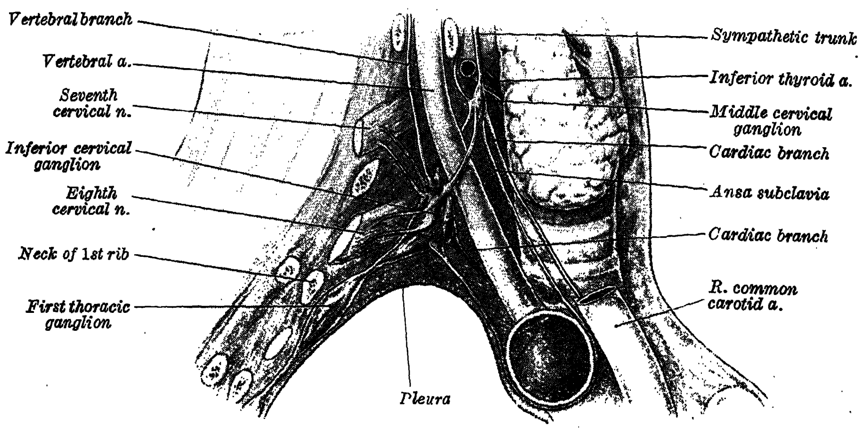
The **lateral branches** of the superior cervical ganglion consist of grey rami communicantes to the upper four cervical nerves and to certain of the cranial nerves. Sometimes the branch to the fourth cervical nerve comes from the

* T. K. Potts (*Journal of Anatomy*, vol. lix. part ii.) has traced as many as three grey rami to each of the lower four cervical nerves.

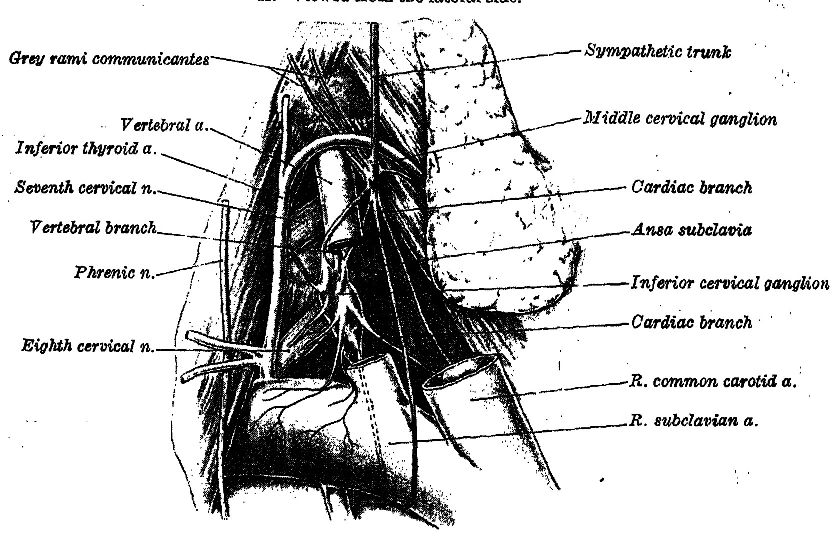
trunk connecting the superior and middle cervical ganglia. Delicate filaments run to the inferior ganglion (ganglion nodosum) of the vagus, and to the hypoglossal nerve; and a branch, named the *jugular nerve*, ascends to the base of the skull, and divides into two twigs, one of which joins the inferior (petrous) ganglion of the glossopharyngeal, and the other the superior (jugular) ganglion of the vagus.

The **medial branches** of the superior cervical ganglion are the laryngopharyngeal and cardiac branches.

FIG. 997.—The middle and inferior cervical ganglia of the right side.



A. Viewed from the lateral side.



B. The same. Viewed from in front.

The *laryngopharyngeal branches* give twigs to the carotid body, and pass to the side of the pharynx, where they join with branches from the glossopharyngeal and vagus nerves to form the *pharyngeal plexus* (p. 1069).

The *cardiac branch* arises by two or more filaments from the superior cervical ganglion, and occasionally receives a twig from the trunk connecting the superior with the middle cervical ganglion. It is said to contain only efferent fibres, which arise in the upper thoracic segments of the spinal cord. It runs down the neck behind the common carotid artery, and in front of the longus cervicis (longus colli) muscle; and crosses in front of the inferior thyroid artery and recurrent laryngeal nerve. The course of the nerve of the right side then differs from that of the left. The *right nerve*, at the root of the neck, passes either in front of or behind the subclavian artery, and along the innominate artery to the back of the arch of the aorta, where it joins the deep part of the cardiac

plexus. It is connected with other branches of the sympathetic; about the middle of the neck it receives filaments from the external laryngeal nerve; lower down, one or two cardiac branches from the vagus nerve join it; and as it enters the thorax it is joined by a filament from the recurrent laryngeal nerve. Filaments from the nerve communicate with the thyroid branches from the middle cervical ganglion. The *left nerve*, in the thorax, runs in front of the left common carotid artery and across the left side of the arch of the aorta, to the superficial part of the cardiac plexus. Sometimes it descends on the right side of the aorta and ends in the deep part of the cardiac plexus.

The **anterior branches** of the superior cervical ganglion ramify upon the common carotid artery, and upon the external carotid artery and its branches, forming around each a delicate plexus in which small ganglia are occasionally found. The plexus surrounding the facial artery supplies a filament to the submandibular ganglion, and the plexus on the middle meningeal artery sends one offset to the otic ganglion, and another, termed the *external petrosal nerve*, to the ganglion of the facial nerve.

The **middle cervical ganglion** (fig. 997), the smallest of the three cervical ganglia, is occasionally wanting. It is usually placed opposite the sixth cervical vertebra, in front of, or close to, the inferior thyroid artery, or it may lie near to the inferior cervical ganglion (*vide infra*). It is probably formed by the coalescence of two ganglia corresponding with the fifth and sixth cervical nerves.

The ganglion sends grey rami communicantes to the fifth and sixth cervical nerves, and sometimes to the fourth and seventh, and gives off thyroid and cardiac branches. It is connected to the inferior cervical ganglion by two or more cords, one of which forms a loop around the subclavian artery, and supplies offsets to it. This loop is intimately related to the cervical pleura and is named the *ansa subclavia*.

The *thyroid branches* run along the inferior thyroid artery to the thyroid gland; they communicate with the superior cardiac, external laryngeal and recurrent laryngeal nerves.

The *cardiac branch*, the largest of the sympathetic cardiac branches, arises from the middle cervical ganglion, or from the trunk connecting the middle with the inferior cervical ganglion. On the *right side* it descends behind the common carotid artery, and at the root of the neck runs either in front of or behind the subclavian artery; it then descends on the trachea, receives a few filaments from the recurrent laryngeal nerve, and joins the right half of the deep part of the cardiac plexus. In the neck, it communicates with the superior cardiac and recurrent laryngeal nerves. On the *left side*, the nerve enters the thorax between the left carotid and subclavian arteries, and joins the left half of the deep part of the cardiac plexus.

The **inferior cervical ganglion** (fig. 997) is situated between the base of the transverse process of the last cervical vertebra and the neck of the first rib, behind the origin of the vertebral artery. Its form is irregular; it is larger than the middle cervical ganglion, and is frequently fused with the first thoracic ganglion. It is probably formed by the coalescence of two ganglia corresponding with the seventh and eighth cervical nerves. In many cases, however, it may be fused with the first or even the first and second thoracic ganglia and is then termed the *stellate ganglion*—the usual condition in many animals. Not uncommonly it may be partly fused with the ganglia corresponding to the sixth, or fifth and sixth, cervical nerves. In the former case the middle cervical ganglion is small and in the latter case it may be absent entirely. This addition to the inferior cervical ganglion lies on an anterior plane to the ganglion proper* and is placed in front of the vertebral artery near its origin, the vessel being embraced by the connexions between the two. In this event the ansa subclavia takes origin from the additional part of the inferior cervical ganglion instead of from the middle cervical ganglion, but loops round the first part of the subclavian artery in the usual way.

The ganglion sends grey rami communicantes to the seventh and eighth cervical nerves, gives off a cardiac branch, supplies branches to blood-vessels, and not infrequently sends a branch to join the vagus nerve.

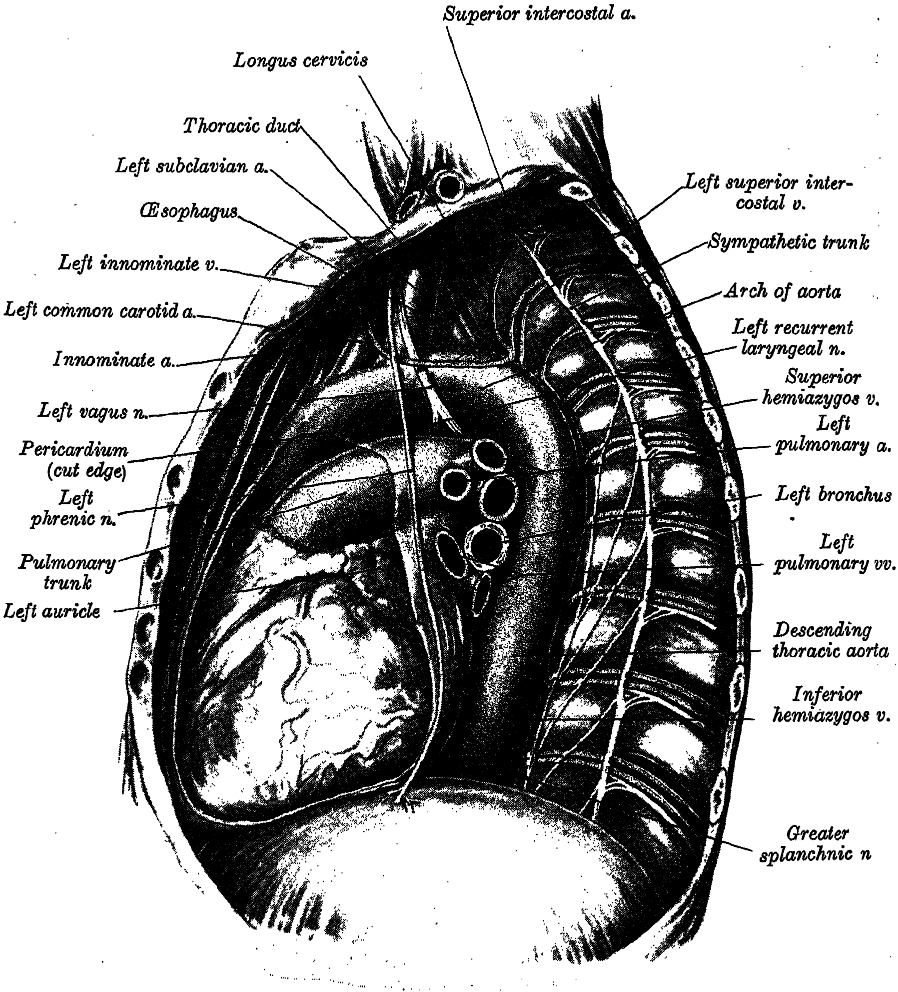
The *cardiac branch* arises from either the inferior cervical or the first thoracic ganglion. It descends behind the subclavian artery and along the front of

* This is the *ganglion intermédiaire* of French anatomists.

the trachea, to join the deep part of the cardiac plexus. Behind the subclavian artery it communicates with the recurrent laryngeal nerve and the cardiac branch of the middle cervical ganglion.

The *offsets to blood-vessels* form plexuses on the subclavian artery and its branches. The plexus on the vertebral artery forms a substantial cord which runs upwards behind the vessels and is continued on the basilar, posterior cerebral and cerebellar arteries. The plexus on the inferior thyroid artery

FIG. 998.—The thoracic portion of the left sympathetic trunk.



accompanies the artery to the thyroid gland, and communicates with the recurrent and external laryngeal nerves, with the cardiac branch of the superior cervical ganglion, and with the plexus on the common carotid artery. The axillary and the brachial arteries and their branches are not supplied by the subclavian plexus but by the branches of the brachial plexus, and especially by the median nerve. The fibres concerned arise in the inferior cervical ganglion and pass to the plexus along the grey rami communicantes. They travel for the most part in the lower trunk of the brachial plexus.

The Thoracic Part of the Sympathetic System (fig. 998)

The **thoracic part** of each sympathetic trunk comprises a series of ganglia, which usually correspond in number to that of the thoracic spinal nerves ; but,

on account of the occasional coalescence of two ganglia, their number is variable. The thoracic ganglia, with the exception of the last two or three, rest against the heads of the ribs, and are covered by the costal pleura ; the last two or three are placed on the sides of the bodies of the corresponding vertebræ. The ganglia are small, and of a greyish colour, and are connected together by the intervening portions of the trunk. The first is larger than the others, and of an elongated form ; it is frequently blended with the inferior cervical ganglion.

Two rami communicantes, a white and a grey, connect each ganglion with its corresponding spinal nerve.

The *branches from the upper five ganglia* are very small ; they supply filaments to the thoracic aorta and its branches. On the aorta they form a delicate plexus (*plexus aorticus thoracalis*) together with filaments from the greater splanchnic nerve. Twigs from the second, third, and fourth ganglia enter the posterior pulmonary plexus ; others, from the second, third, fourth and fifth ganglia, pass to the deep cardiac plexus.*

The *branches from the lower seven ganglia* are large, and white in colour ; they distribute filaments to the aorta, and unite to form the greater, the lesser and the lowest splanchnic nerves.

The *greater splanchnic nerve* is of a considerable size, and consists mainly of medullated, preganglionic fibres ; it is formed by branches from the fifth to the ninth or tenth thoracic ganglia, but the fibres in the higher branches may be traced upwards in the sympathetic trunk as far as the first or second thoracic ganglion. It descends obliquely on the bodies of the vertebræ, perforates the crus of the diaphragm, and ends in the cœliac ganglion. A ganglion [*ganglion splanchnicum*] exists on this nerve opposite the eleventh or twelfth thoracic vertebra.

The *lesser splanchnic nerve* is formed by filaments from the ninth and tenth, sometimes the tenth and eleventh, thoracic ganglia, and from the trunk between the ganglia. It pierces the diaphragm with the preceding nerve, and joins the aorticorenal ganglion.

The *lowest splanchnic nerve* arises from the last thoracic ganglion. It gains the abdomen with the sympathetic trunk, and ends in the renal plexus.

The Lumbar Part of the Sympathetic System (fig. 999)

The lumbar part of each sympathetic trunk is situated in front of the vertebral column, along the medial margin of the psoas major. It consists usually of four lumbar ganglia, connected together by the intervening portions of the trunk. It is continuous above with the thoracic portion, deep to the medial arcuate ligament (medial lumbocostal arch) ; below with the pelvic portion, behind the common iliac artery.

Grey rami communicantes pass from all the ganglia to the lumbar spinal nerves. Many of these fibres travel in the femoral nerve and its saphenous branch and in the obturator nerve and are distributed at intervals to the femoral artery and its branches. The first and second, and sometimes the third, lumbar nerves send white rami communicantes to the corresponding ganglia. The rami communicantes are of considerable length, and accompany the lumbar arteries round the sides of the bodies of the vertebræ, deep to the fibrous arches which give origin to some of the fibres of the psoas major.

Of the *branches of distribution*, some pass in front of the aorta, and join the abdominal aortic plexus ; others run downwards and form plexuses around the common, the external and the internal iliac arteries ; while others cross in front of the common iliac arteries, and assist in forming the hypogastric plexus.

The Pelvic Part of the Sympathetic System (fig. 996)

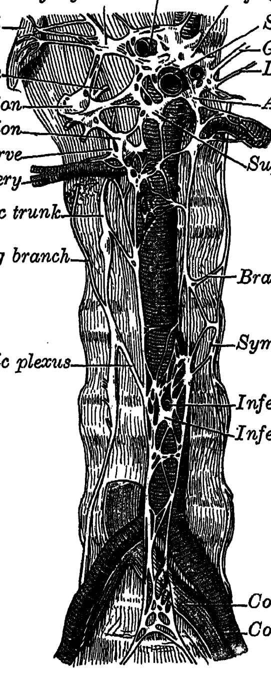
The pelvic part of each sympathetic trunk is situated in front of the sacrum, medial to, or overlapping, the anterior sacral foramina. It comprises four or five small sacral ganglia, connected by the intervening portions of the trunk. It is continuous above with the lumbar part, while below, the two pelvic sympathetic trunks converge, and unite on the front of the coccyx in a small ganglion, which is named the *ganglion impar*.

* Ionescu, D., and Enachescu, M., *Zeitschr. f. Anat. und Entwg.* Bd. 85, 1928.

Grey rami communicantes pass from the ganglia to the sacral and coccygeal nerves. Many of these fibres reach the medial popliteal (tibial) nerve and are distributed to the popliteal artery and its branches. No white rami communicantes pass to this part of the sympathetic trunk.

The *branches of distribution* communicate on the front of the sacrum with the corresponding branches from the opposite side; twigs from the first two ganglia join the pelvic plexuses, and others form a plexus on the median sacral artery. Filaments are distributed to the glomus coccygeum (coccygeal body) from the loop uniting the two trunks.

FIG. 999.—The abdominal portion of the sympathetic trunks, with the cœliac and aortic plexuses. (After Henle.)



The following facts concerning the course of the sympathetic nerve-fibres have been arrived at by experiments on lower animals, chiefly dogs, but they probably hold good for the human sympathetic system:

The preganglionic sympathetic fibres for the head and neck leave the spinal cord through the upper five thoracic nerves (chiefly through the second and third nerves). They ascend in the cervical part of the sympathetic trunk and end in the superior cervical ganglion. The fibres arising from the cells of this ganglion are vasoconstrictor for the blood-vessels, secretory for the salivary and sudoriferous glands, and dilator for the pupil.

The accelerator fibres of the heart leave mainly through the second and third thoracic nerves and pass to the *stellate*,* and the inferior and middle cervical ganglia. From the cells of these ganglia fibres are distributed to the heart. The *afferent* fibres from the heart run in the middle and inferior cervical cardiac and in the thoracic cardiac nerves. Having entered the sympathetic trunk, they pass to the posterior nerve-roots of the second to the fourth or fifth thoracic nerves.

Fibres leave the thoracic spinal nerves (mainly the lower six) and are conveyed through the splanchnic nerves to the cœliac ganglion, from the cells of which fibres pass to the blood-vessels and viscera of the abdominal cavity. Fibres from the lower thoracic and upper three or four lumbar nerves pass through the ganglia of the lumbar part of the sympathetic trunk to the inferior mesenteric ganglion; from this ganglion fibres are conveyed through the hypogastric and pelvic plexuses to the pelvic viscera.

* In the dog the upper four thoracic ganglia of the sympathetic trunk are fused into one mass which is named the *stellate* ganglion.

The constrictor fibres for the blood-vessels of the upper limbs leave the thoracic nerves from about the fourth to the tenth inclusive; those for the lower limbs through the lower two or three thoracic and upper three lumbar nerves; the former have their synapses in the stellate ganglion, the latter in the sixth and seventh lumbar and first sacral ganglia.

THE GREAT PLEXUSES OF THE SYMPATHETIC

The great plexuses of the sympathetic are aggregations of nerves and ganglia, situated in the thoracic, abdominal and pelvic cavities, and named the cardiac, cœliac and hypogastric plexuses. From the plexuses branches are given to the thoracic, abdominal and pelvic viscera.

The Cardiac Plexus (fig. 996)

The **cardiac plexus** is situated at the base of the heart, and is divided into a *superficial* and a *deep part*, which are, however, closely connected.

The **superficial part of the cardiac plexus** lies below the arch of the aorta, in front of the right pulmonary artery. It is formed by the cardiac branch of the superior cervical ganglion of the left sympathetic trunk, and the lower of the two cervical cardiac branches of the left vagus. A small ganglion, termed the *cardiac ganglion*, is usually found in this plexus, and is situated immediately below the arch of the aorta, on the right side of the ligamentum arteriosum. This ganglion is probably a part of the parasympathetic system and acts as a cell-station for vagal fibres only. The superficial part of the cardiac plexus gives branches (*a*) to the deep part of the plexus; (*b*) to the right coronary plexus; and (*c*) to the left anterior pulmonary plexus.

The **deep part of the cardiac plexus** is situated in front of the bifurcation of the trachea, above the point of division of the pulmonary trunk, and behind the aortic arch. It is formed by the cardiac nerves derived from the cervical and upper thoracic ganglia of the sympathetic trunk, and the cardiac branches of the vagus and recurrent laryngeal nerves. The only cardiac nerves which do not join the deep part of the cardiac plexus are those which pass to the superficial part of the plexus.

The branches from the *right half* of the deep part of the cardiac plexus pass, some in front of, and others behind, the right pulmonary artery; the former, the more numerous, transmit a few filaments to the right anterior pulmonary plexus, and are then continued onwards to form part of the right coronary plexus; those behind the pulmonary artery distribute a few filaments to the right atrium, and are then continued onwards to form part of the left coronary plexus.

The *left half* of the deep part of the cardiac plexus is connected with the superficial part of the plexus, and gives filaments to the left atrium, and to the left anterior pulmonary plexus, and is then continued to form the greater part of the left coronary plexus.

The **left coronary plexus** is larger than the anterior, and accompanies the left coronary artery; it is formed chiefly by filaments prolonged from the left half of the deep part of the cardiac plexus, and by a few from the right half. It gives branches to the left atrium and ventricle.

The **right coronary plexus** is formed partly from the superficial and partly from the deep parts of the cardiac plexus. It accompanies the right coronary artery, and gives branches to the right atrium and ventricle.

The sympathetic cardiac nerves are the accelerator nerves of the heart.

The *efferent* sympathetic fibres arise in the upper thoracic segments of the spinal cord, down to and including the fifth, emerge in the corresponding anterior nerve-roots and travel via the white rami communicantes to the sympathetic trunk, in which many of them ascend to the cervical ganglia before being relayed. The *afferent* sympathetic fibres run in the cardiac branches of the middle and inferior cervical ganglia and the thoracic cardiac nerves and reach the spinal cord through the posterior nerve-roots of T. 2 to T. 5.

The fibres derived from the upper thoracic segments of the spinal cord are distributed to the ascending aorta, the pulmonary trunk and the ventricles; those from the lower segments supply the atria.

The Cœliac Plexus (figs. 996, 999, 1000)

The **cœliac** or **solar plexus**, the largest of the three great sympathetic plexuses, is situated at the level of the upper part of the first lumbar vertebra, and is composed of a dense network of nerve-fibres which unite together two large ganglia, termed the cœliac ganglia. It surrounds the cœliac artery and the root of the superior mesenteric artery. It lies behind the stomach and the omental bursa, in front of the crura of the diaphragm and the commencement of the abdominal aorta, and between the suprarenal glands. The plexus and the ganglia receive the greater and lesser splanchnic nerves of both sides and some filaments from the right vagus, and give off numerous secondary plexuses along the neighbouring arteries.

The *cœliac ganglia* are two large irregularly-shaped masses, not unlike lymph glands in appearance, placed, one on each side of the median plane, in front of the crura of the diaphragm and medial to the suprarenal glands, that on the right side being placed behind the inferior vena cava. The upper part of each ganglion is joined by the greater splanchnic nerve, while the lower part, which is more or less detached and is often named the *aorticorenal* ganglion, receives the lesser splanchnic nerve and gives off the greater part of the renal plexus.

The secondary plexuses springing from or connected with the cœliac plexus are the following:

Phrenic.	Splenic.	Suprarenal.	Testicular (or ovarian).
Hepatic.	Left gastric.	Renal.	Superior mesenteric.
	Abdominal aortic.	Inferior mesenteric.	

The **phrenic plexus** accompanies the corresponding (inferior) phrenic artery to the diaphragm, some filaments passing to the suprarenal gland. It arises from the upper part of the cœliac ganglion, and is larger on the right than on the left side. It receives one or two branches from the phrenic nerve. At the point of junction of the right phrenic plexus with the phrenic nerve there is a small ganglion (*ganglion phrenicum*). This plexus distributes some branches to the inferior vena cava, and to the suprarenal and hepatic plexuses.

The **hepatic plexus**, the largest offset from the cœliac plexus, receives filaments from the left and right vagus and right phrenic nerves. It accompanies the hepatic artery, ramifying upon its branches, and upon those of the portal vein, in the substance of the liver. Branches from this plexus accompany all the branches of the hepatic artery. The plexus exercises a controlling and regulating influence over both carbohydrate and protein metabolism in the liver. Its vagal constituents are believed to be motor to the musculature of the gall-bladder and bile ducts and inhibitory to the sphincter of the bile duct. A considerable plexus accompanies the gastroduodenal artery and is continued as the *right gastro-epiploic plexus* on the right gastro-epiploic artery along the greater curvature of the stomach, where it unites with offshoots from the splenic plexus.

The **splenic plexus** is formed by branches from the cœliac plexus, left cœliac ganglion and right vagus nerve. It accompanies the splenic artery to the spleen, giving off, in its course, subsidiary plexuses along the various branches of the artery. The terminal branches supply the unstriped muscle of the splenic capsule and trabeculæ.

The **left gastric plexus** accompanies the left gastric artery along the lesser curvature of the stomach, and joins with the gastric branches of the vagus nerves. The gastric sympathetic nerves are motor to the pyloric sphincter but inhibitory to the muscular coats of the stomach.

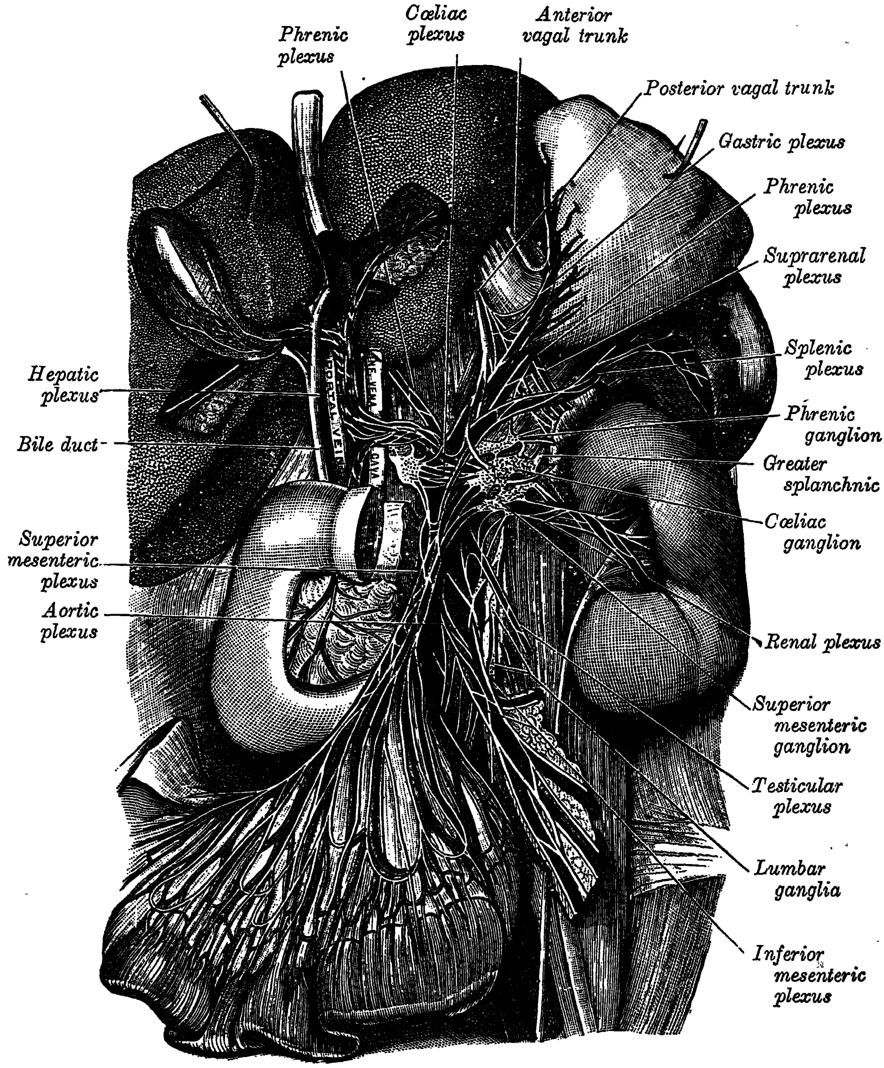
The **suprarenal plexus** is formed by branches from the cœliac plexus, from the cœliac ganglion, and from the phrenic and greater splanchnic nerves, a ganglion being formed at the point of junction with the latter nerve. The plexus supplies the suprarenal gland, and is distributed chiefly to its medullary portion; its branches are remarkable for their large size in comparison with that of the organ they supply.

The **renal plexus** is formed by filaments from the cœliac plexus, the aorticorenal ganglion, and the aortic plexus. It is joined also by the lowest splanchnic nerve and by branches from the vagus.* The nerves from these sources, fifteen

* O. Renner, *Die Innervation der Niere. Die Lebensnerven* (L. R. Müller), Berlin, 1924.

or twenty in number, have a few ganglia developed upon them. They accompany the branches of the renal artery into the kidney; some filaments are distributed to the testicular plexus and to the ureter, and, on the right side, to the inferior vena cava. The available evidence suggests strongly that the renal sympathetic nerves are entirely vasomotor in function.

FIG. 1000.—The cœliac ganglia with the sympathetic plexuses of the abdominal viscera radiating from the ganglia. (From Toldt's *Atlas*, published by Messrs. Redman, Ltd., London.)



The **testicular plexus** is derived from the renal plexus, and receives twigs from the aortic plexus. It accompanies the testicular artery to the testis. In the female the **ovarian plexus** arises from the renal plexus, and, accompanying the ovarian artery, is distributed to the ovary and the fundus of the uterus.

The sympathetic nerves to the intestine are motor to the ileocolic sphincter but inhibitory to the muscular coats of the gut. In addition, they convey vasoconstrictor fibres.

The **superior mesenteric plexus** is a continuation of the lower part of the cœliac plexus, and receives a branch from the junction of the right vagus nerve with the latter plexus. It surrounds the superior mesenteric artery, accompanies it into the mesentery, and divides into a number of secondary plexuses which are distributed to the parts supplied by the artery, viz. pancreatic

branches to the pancreas ; jejunal and ileal branches to the small intestine ; ileocolic, right colic, and middle colic branches, which supply the corresponding parts of the large intestine. The nerves composing this plexus are white in colour and firm in texture ; the *superior mesenteric ganglion* is situated in the upper part of the plexus close to the origin of the superior mesenteric artery.

The **abdominal aortic plexus** is formed by branches from the cœliac plexus and ganglia, and receives filaments from some of the lumbar ganglia. It is situated upon the sides and front of the aorta, between the origins of the superior and inferior mesenteric arteries. From this plexus parts of the testicular, the inferior mesenteric, the iliac and the hypogastric plexuses arise ; it also distributes filaments to the inferior vena cava.

The **inferior mesenteric plexus** is derived chiefly from the aortic plexus. It surrounds the inferior mesenteric artery, and just below the origin of this vessel the *inferior mesenteric ganglion* is situated. The plexus divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery ; thus the left colic plexuses supply the descending and pelvic parts of the colon ; and the superior rectal plexus supplies the rectum and joins in the pelvis with branches from the pelvic plexuses. The colic sympathetic nerves are inhibitory to the muscular coats of the colon and rectum.

The Hypogastric Plexus (fig. 996)

The **hypogastric plexus** is situated in front of the left common iliac vein, the last lumbar vertebra and the promontory of the sacrum, between the two common iliac arteries. It is formed by the union of numerous filaments—the so-called " presacral nerves "—which descend on each side from the aortic plexus, and from the lumbar ganglia. It divides below into two portions which are named the *right* and *left pelvic plexuses*.

The Pelvic Plexuses (fig. 996)

The two **pelvic plexuses** supply the viscera of the pelvic cavity, and are situated at the sides of the rectum in the male, and at the sides of the rectum and vagina in the female. Each is formed by a continuation of the hypogastric plexus, and by a few filaments from the first two ganglia of the sacral part of the sympathetic trunk. The parasympathetic visceral branches of the second and third sacral nerves [the pelvic splanchnics] join the sympathetic nerves of the pelvic plexuses, and minute ganglia are found at the points of junction. From the pelvic plexuses numerous branches are distributed to the viscera of the pelvis. They accompany the branches of the internal iliac artery.

The **middle rectal plexus** arises from the upper part of the pelvic plexus ; it supplies the rectum, and joins with branches of the superior rectal plexus.

The **vesical plexus** arises from the fore parts of the pelvic plexuses. The nerves composing it are numerous and, as it is a mixed sympathetic and parasympathetic plexus, contain a large proportion of medullated preganglionic nerve-fibres. They accompany the vesical arteries, and are distributed to the sides and fundus of the bladder. Numerous filaments also pass to the vesiculæ seminales and vasa deferentia ; those accompanying the vasa deferentia join, on the spermatic cord, with branches from the testicular plexuses. The vesical sympathetic nerves convey motor fibres to the sphincter and inhibitory fibres to the muscular coats of the bladder.

The **prostatic plexus** is continued from the lower parts of the pelvic plexuses. The nerves composing it are of large size. They are distributed to the prostate, vesiculæ seminales, and the corpora cavernosa and corpus spongiosum of the penis. The nerves supplying the corpora cavernosa consist of two sets, the lesser and greater cavernous nerves, which arise from the fore part of the prostatic plexus, and, after joining with branches from the pudendal nerve, pass forwards below the pubic arch.

The *lesser cavernous nerves* perforate the fibrous covering of the penis, near its root, and are distributed to its erectile tissue.

The *greater cavernous nerve* passes forwards along the dorsum of the penis, joins with the dorsal nerve of the penis, and is distributed to the corpora cavernosa.

The **vaginal plexus** arises from the lower parts of the pelvic plexuses. It is distributed to the walls of the vagina and to the erectile tissue of the vestibule. The nerves composing this plexus contain, like the vesical, a large proportion of preganglionic parasympathetic nerve-fibres.

The **uterine plexus** accompanies the uterine artery along the side of the uterus, between the layers of the broad ligament, and communicates with the ovarian plexus. Its fibres are chiefly distributed to the neck, and the lower part of the body, of the uterus. A collection of small ganglia which together form the *uterine cervical ganglion* is situated at the side of the neck of the uterus.

Applied Anatomy.—Little is known as to the connexion between the numerous microscopical alterations (pigmentation, atrophy, hæmorrhage, fibrosis) that have been described in the sympathetic nervous system, and the functional changes that ensue therefrom. Grosser lesions due to stabs, bullet-wounds, or the pressure of new growths, may cause either irritative or paralytic symptoms. In *paralysis* of the cervical sympathetic on one side, the pupil is small and does not dilate when shaded or on the instillation of cocaine, although it contracts still further when brightly illuminated; it also loses the ciliospinal reflex, failing to dilate when the skin of the neck is pinched. The palpebral fissure narrows from paralysis of the involuntary muscle of the eyelid, and the eyeball sinks backwards into the orbit—enophthalmos. The superficial vessels of the face and scalp are at first dilated, but later they contract. Anidrosis, or absence of sweating, is often noted on the affected side. *Irritation* of the cervical sympathetic produces signs mainly the converse of those described above. We have no definite knowledge of the signs and symptoms that follow lesions of the thoracic or lumbar parts of the sympathetic system. It is likely, however, that a number of nervous disorders characterised by persistent vascular disturbances, such as dilatation of the vessels with throbbing, flushing, sweating, and localised œdema, or contraction of the vessels with pallor, chilliness, pain, and malnutrition of the affected parts, are due to implication of the sympathetic nervous system.

The operation of *periarterial sympathectomy* has been introduced of recent years in an attempt to deprive an artery of its sympathetic innervation, particularly in cases of intermittent claudication. It consists in the removal of a complete ' cuff ' of the tunica adventitia, in which the vascular nerves lie, but, although good results have followed in many cases, there is no anatomical basis for the operation. The aortic plexus is continued along the large branches of the aorta, and this source of supply may be cut off completely by the procedure, but it does not constitute the exclusive supply of the large arteries. Numerous branches of sympathetic origin join the vessels from the nerves which run close to them in their course. For example, the median nerve in the arm supplies numerous filaments to the brachial artery, and the femoral, saphenous and obturator nerves in the thigh give branches to the femoral artery. On this account the removal of a ' cuff ' of the tunica adventitia can only produce a local denervation of the vessel.

Complete removal of the cervical ganglia and the cervical part of the sympathetic trunk has been carried out in cases of bronchial asthma with varying success. In view of the fact that the bronchoconstrictors are supplied by the vagus (p. 1074), it would appear that the operation can only be expected to produce beneficial results when the condition is due to reflexes of peripheral origin. In such cases the removal of the cervical sympathetic trunk eliminates some of the afferent impulses.

The whole of the sympathetic innervation of the upper limb can be cut off by the excision of the first and second thoracic ganglia, and the portion of the trunk which connects them. This operation has been carried out with successful results in cases of Raynaud's disease affecting the upper limbs. Although the bilateral excision of the first and second thoracic ganglia cuts off a large part of the sympathetic innervation of the heart, the cardiac rhythm is not greatly disturbed. The operation is performed through a dorsal, vertical incision and involves the excision of the vertebral end of the second rib and the transverse process of the second thoracic vertebra.

Recently, the lumbar part of the sympathetic trunk and its rami have been subjected to operation in cases of Hirschsprung's disease, or congenital megalocolon. On the grounds that the dilated condition of the gut is attributable to overaction of the inhibitory influence of the sympathetic, the white ramus communicans of the first lumbar ganglion (and sometimes that of the second as well) and the medial branches of the lumbar ganglia are divided and the trunk itself is cut through below the fourth lumbar ganglion. Similar operations have been performed for spastic conditions of the vessels of the lower limb.

Division of the ' presacral nerves ' has recently been carried out for pain associated with disease of the pelvic organs on the assumption that the afferent fibres concerned reach the spinal cord by this route. A similar operation has been performed to hasten the onset of ' automatic bladder ' in lesions of the spinal cord.

THE ORGANS OF THE SENSES AND THE SKIN

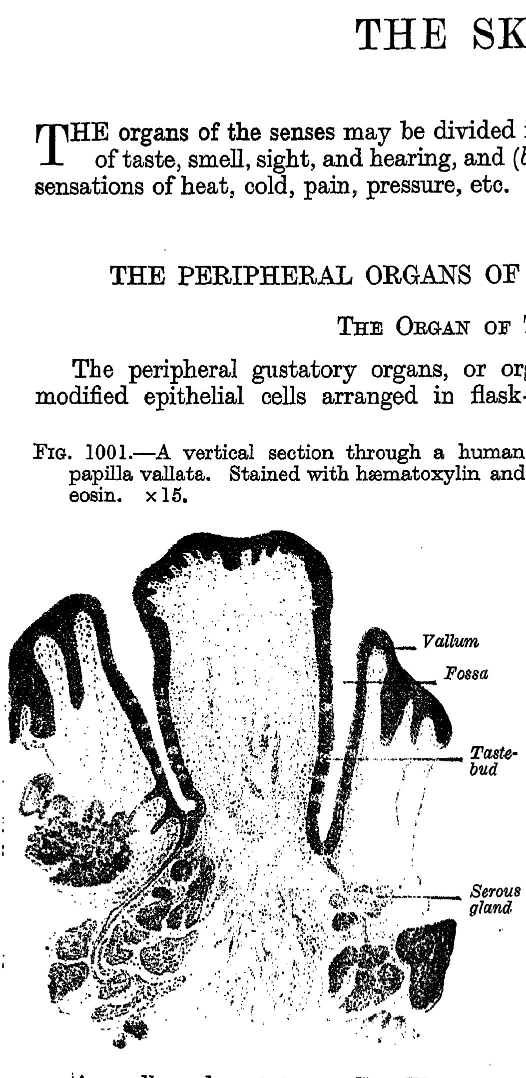
THE organs of the senses may be divided into (*a*) those of the special senses of taste, smell, sight, and hearing, and (*b*) those associated with the general sensations of heat, cold, pain, pressure, etc.

THE PERIPHERAL ORGANS OF THE SPECIAL SENSES

The Organ of Taste

The peripheral gustatory organs, or organs of taste, consist of certain modified epithelial cells arranged in flask-shaped groups termed *gustatory calyculi* or *taste-buds*, which are found on the tongue and adjacent parts. They occupy nests in the stratified epithelium (fig. 1001), and are very numerous on the sides of the papillæ vallatæ and less so on the walls surrounding the papillæ. They are found also in the epithelial covering of the sides and posterior part of the tongue. They are very plentiful over the folia linguæ, just in front of the lingual attachment of the palato-glossal arch. They are present also on the under surface of the soft palate, and on the posterior surface of the epiglottis.

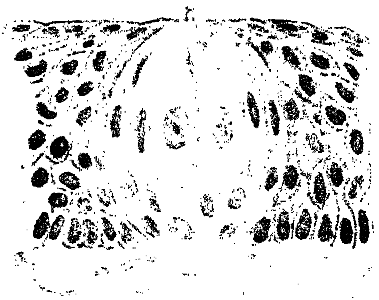
Fig. 1001.—A vertical section through a human papilla vallata. Stained with hæmatoxylin and eosin. ×15.



Structure.—Each taste-bud is flask-shaped (fig. 1002), its broad base resting on the corium, and its neck opening between the cells of the epithelium by an orifice termed the *gustatory pore*. The bud consists of supporting cells and gustatory cells. The *supporting cells* are mostly arranged like the staves of a cask, and form a complete envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The *gustatory cells* occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near its centre. The peripheral process of the cell ends at the gustatory pore in a fine hair-like filament, named the *gustatory hair*. The central process passes towards the deep part of the bud, and there ends in a single or branched extremity. The nerve-fibres, after losing their medullary sheaths, enter the taste-bud, and end in fine fibrils between the gustatory cells; other nerve-fibrils end between the epithelial cells which surround the taste-bud, but these are believed to be nerves of ordinary sensation and not gustatory.

Nerves of taste.—The chorda tympani nerve, derived from the facial nerve (p. 1061), and distributed with the lingual nerve, is the nerve of taste for the anterior two-thirds of the tongue; the glossopharyngeal is the nerve of taste for the posterior one-third of the tongue and for the soft palate. The internal laryngeal branch of the vagus innervates the taste-buds in the epiglottis.

Fig. 1002.—A section through a taste-bud from the human tongue. Stained with hæmatoxylin and eosin. × 450.



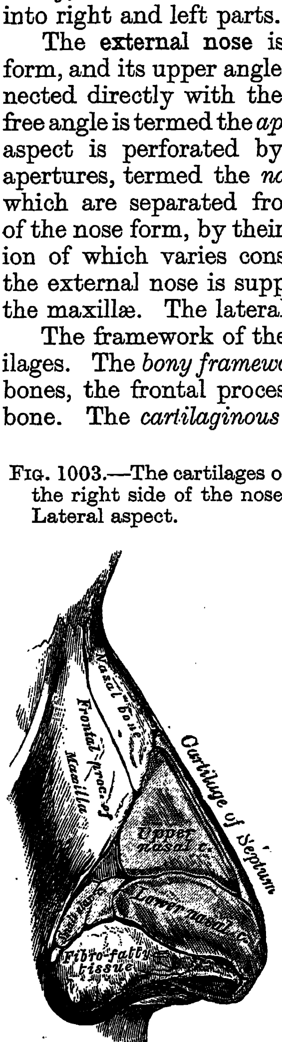
The Organ of Smell

The peripheral olfactory organ consists of the *external nose*, and the *nasal cavity*, which is divided by a septum into right and left parts.

The **external nose** is pyramidal in form, and its upper angle, or *root*, is connected directly with the forehead; its free angle is termed the *apex*. Its inferior aspect is perforated by two elliptical apertures, termed the *nares* or *nostrils*, which are separated from each other by the septum. The lateral surfaces of the nose form, by their union in the medial plane, the *dorsum nasi*, the direction of which varies considerably in different individuals; the upper part of the external nose is supported by the nasal bones and the frontal processes of the maxillæ. The lateral surfaces end below in the rounded *alæ nasi*.

The framework of the external nose is composed of bones and hyaline cartilages. The *bony framework*, which supports its upper part, consists of the nasal bones, the frontal processes of the maxillæ, and the nasal part of the frontal bone. The *cartilaginous framework* consists of the septal cartilage, the upper and lower nasal cartilages, and the small cartilages of the ala (figs. 1003-1005). These are connected to one another and to the bones by the continuity of the perichondrium and the periosteum.

Fig. 1003.—The cartilages of the right side of the nose. Lateral aspect.



The *septal cartilage* (figs. 1005, 1006), somewhat quadrilateral in form, and thicker at its margins than at its centre, forms almost the whole of the septum between the anterior parts of the nasal cavity. The upper part of its anterosuperior margin is connected to the posterior border of the internasal suture; the middle part is continuous with the upper nasal cartilages; the lower part is attached to these cartilages by the perichondrium. Its antero-inferior border is connected on each side to the septal process (medial crus) of the lower nasal cartilage. Its postero-superior border is joined to the perpendicular plate of the ethmoid bone, and its postero-inferior border is attached to the vomer and to the nasal crest of the maxillæ. The cartilage of the septum may extend backwards (especially in children) as a narrow process, termed the *sphenoidal process*, for some distance between the vomer and the perpendicular plate of the ethmoid bone. The anterior-inferior part of the nasal septum is freely movable, and hence is named the *septum mobile nasi*; it is not formed by the cartilage of the septum, but by the septal processes of the lower nasal cartilages and by the skin.

The *upper nasal cartilage* (lateral cartilage) (fig. 1003) is situated below the inferior margin of the nasal bone, and is triangular in shape. Its anterior margin is thicker than the posterior, and its upper part is continuous with the cartilage of the septum, but its lower part is separated from this cartilage by a narrow fissure; its superior margin is attached to the nasal bone and the frontal process of the maxilla; its inferior margin is connected by fibrous tissue with the lower nasal cartilage.

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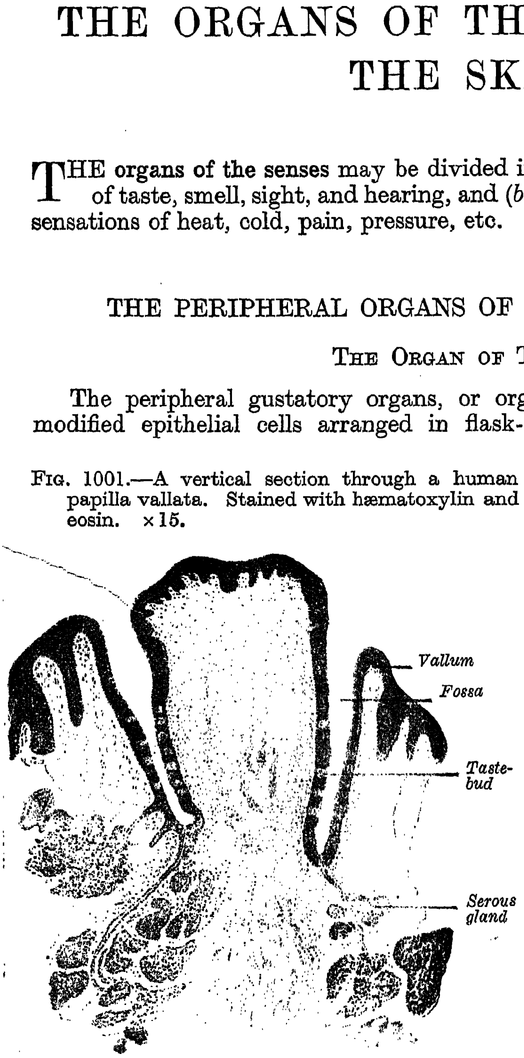

Structure.—Each taste-bud is flask-shaped (fig. 1002), its broad base resting on the corium, and its neck opening between the cells of the epithelium by an orifice termed the *gustatory pore*. The bud consists of supporting cells and gustatory cells. The *supporting cells* are mostly arranged like the staves of a cask, and form a complete envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The *gustatory cells* occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near its centre. The peripheral process of the cell ends at the gustatory pore in a fine hair-like filament, named the *gustatory hair*. The central process passes towards the deep part of the bud, and there ends in a single or branched extremity. The nerve-fibres, after losing their medullary sheaths, enter the taste-bud, and end in fine fibrils between the gustatory cells; other nerve-fibrils end between the epithelial cells which surround the taste-bud, but these are believed to be nerves of ordinary sensation and not gustatory.

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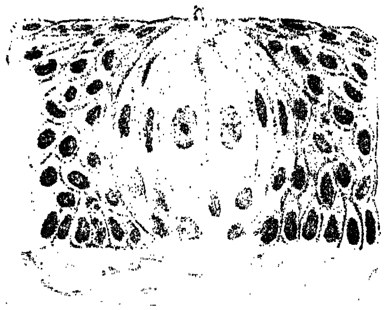
FIG. 1002.—A section through a taste-bud from the human tongue. Stained with hæmatoxylin and eosin. × 450.



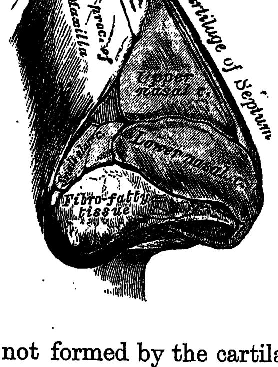
The Organ of Smell

The peripheral olfactory organ consists of the *external nose*, and the *nasal cavity*, which is divided by a septum into right and left parts.

The **external nose** is pyramidal in form, and its upper angle, or *root*, is connected directly with the forehead; its free angle is termed the *apex*. Its inferior aspect is perforated by two elliptical apertures, termed the *nares* or *nostrils*, which are separated from each other by the septum. The lateral surfaces of the nose form, by their union in the medial plane, the *dorsum nasi*, the direction of which varies considerably in different individuals; the upper part of the external nose is supported by the nasal bones and the frontal processes of the maxillæ. The lateral surfaces end below in the rounded *alæ nasi*.

The framework of the external nose is composed of bones and hyaline cartilages. The *bony framework*, which supports its upper part, consists of the nasal bones, the frontal processes of the maxillæ, and the nasal part of the frontal bone. The *cartilaginous framework* consists of the septal cartilage, the upper and lower nasal cartilages, and the small cartilages of the ala (figs. 1003-1005). These are connected to one another and to the bones by the continuity of the perichondrium and the periosteum.

FIG. 1003.—The cartilages of the right side of the nose. Lateral aspect.



The *septal cartilage* (figs. 1005, 1006), somewhat quadrilateral in form, and thicker at its margins than at its centre, forms almost the whole of the septum between the anterior parts of the nasal cavity. The upper part of its anterosuperior margin is connected to the posterior border of the internasal suture; the middle part is continuous with the upper nasal cartilages; the lower part is attached to these cartilages by the perichondrium. Its antero-inferior border is connected on each side to the septal process (medial crus) of the lower nasal cartilage. Its postero-superior border is joined to the perpendicular plate of the ethmoid bone, and its postero-inferior border is attached to the vomer and to the nasal crest of the maxillæ. The cartilage of the septum may extend backwards (especially in children) as a narrow process, termed the *sphenoidal process*, for some distance between the vomer and the perpendicular plate of the ethmoid bone. The anterior-inferior part of the nasal septum is freely movable, and hence is named the *septum mobile nasi*; it is not formed by the cartilage of the septum, but by the septal processes of the lower nasal cartilages and by the skin.

The *upper nasal cartilage* (lateral cartilage) (fig. 1003) is situated below the inferior margin of the nasal bone, and is triangular in shape. Its anterior margin is thicker than the posterior, and its upper part is continuous with the cartilage of the septum, but its lower part is separated from this cartilage by a narrow fissure; its superior margin is attached to the nasal bone and the frontal process of the maxilla; its inferior margin is connected by fibrous tissue with the lower nasal cartilage.

The *lower nasal cartilage* (greater alar cartilage) (figs. 1003, 1004) is a thin, flexible plate which is situated below the upper nasal cartilage, and is bent acutely around the anterior part of the naris. The medial part of the plate is narrow, and is termed the *septal process*. It is loosely connected by fibrous tissue to that of the opposite cartilage, and to the anterō-inferior part of the septal cartilage, thus helping to form the movable, lower part of the nasal septum (septum mobile nasi). The upper border of the lateral part of the lower nasal cartilage is attached by fibrous tissue to the lower border of the upper nasal cartilage. Its posterior, narrow end is connected with the frontal process of the maxilla by a tough fibrous membrane, in which three or four small cartilaginous plates, termed the *small cartilages of the ala* (fig. 1003), are found. Its lower, free edge falls short of the lateral margin of the naris, the lower part of ala nasi being formed by fatty and fibrous tissue covered with skin. In front, the lower nasal cartilages are separated by a notch which corresponds with the apex of the nose.

FIG. 1004.—The cartilages of the nose. Inferior aspect.

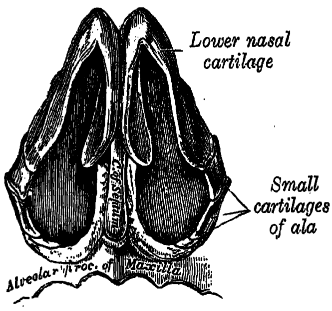
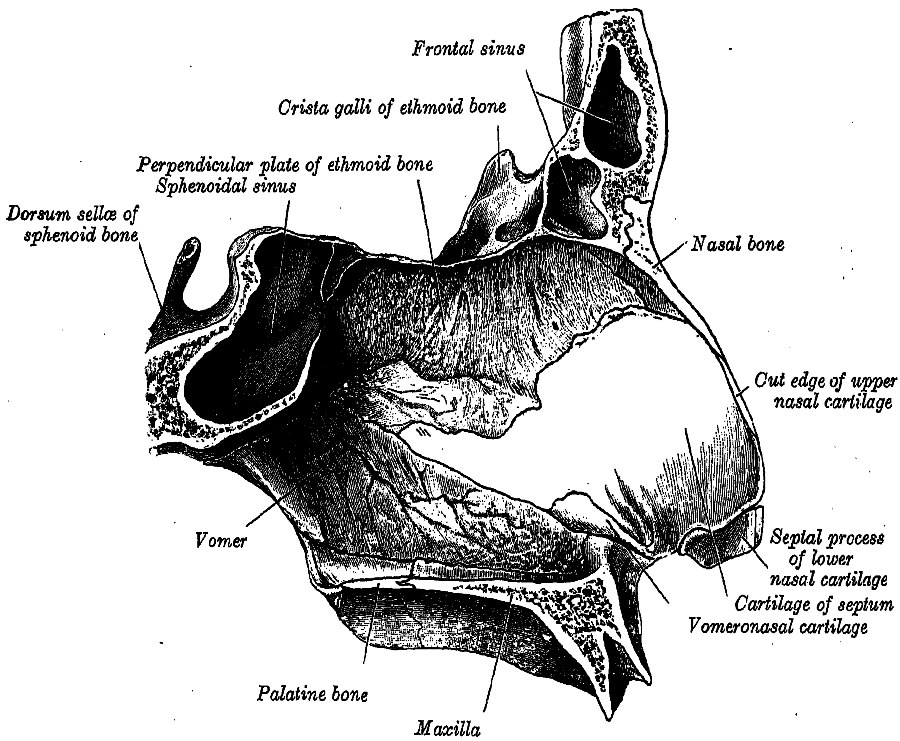


FIG. 1005.—The bones and cartilages of the septum of the nose. Right surface.



The *muscles* acting on the external nose have been described on p. 527.

The *skin* of the dorsum and sides of the nose is thin, and loosely connected with the subjacent parts; but over the tip and alæ it is thicker and more firmly adherent, and is furnished with a large number of sebaceous follicles, the orifices of which are usually very distinct.

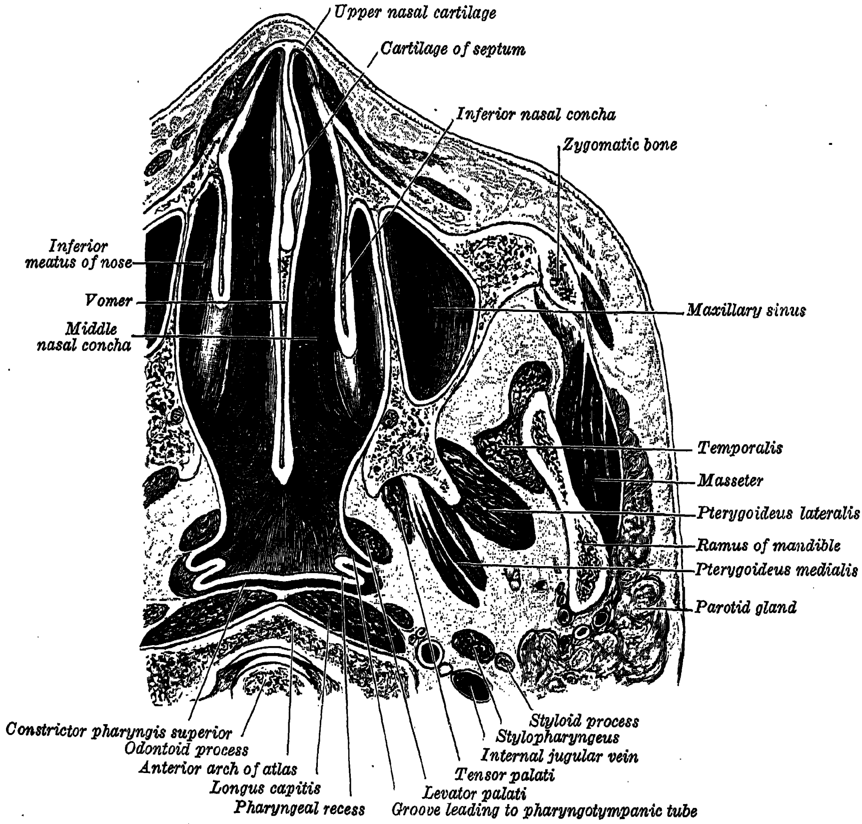
The *arteries* of the external nose are the alar and septal branches of the facial (external maxillary) artery, which supply the ala and lower part of the septum; and the dorsal

nasal branch of the ophthalmic artery and the infra-orbital branch of the maxillary artery, which supply the lateral aspects and the dorsum. The *veins* end in the anterior facial and ophthalmic veins.

The *nerves* for the muscles of the nose are derived from the facial nerve, while the skin receives branches from the ophthalmic nerve, through its infratrochlear branch and the external nasal nerve (p. 1045), and from the infra-orbital branch of the maxillary nerve.

Nasal cavity.—The nasal cavity is subdivided into right and left halves by the nasal septum (fig. 1006). They open on the face through the nares, and communicate behind with the nasal part of the pharynx through the posterior

FIG. 1006.—A transverse section through the anterior part of the head at a level just below the apex of the odontoid process. Viewed from below.



nasal apertures. The *nares* are somewhat pear-shaped apertures, each measuring from 1·5 cm. to 2 cm. anteroposteriorly, and from 0·5 cm. to 1 cm. transversely at its widest part. The *posterior nasal apertures* are two oval openings each measuring about 2·5 cm. in the vertical, and 1·25 cm. in the transverse direction.

For the description of the bony boundaries of the nasal cavity, see p. 273.

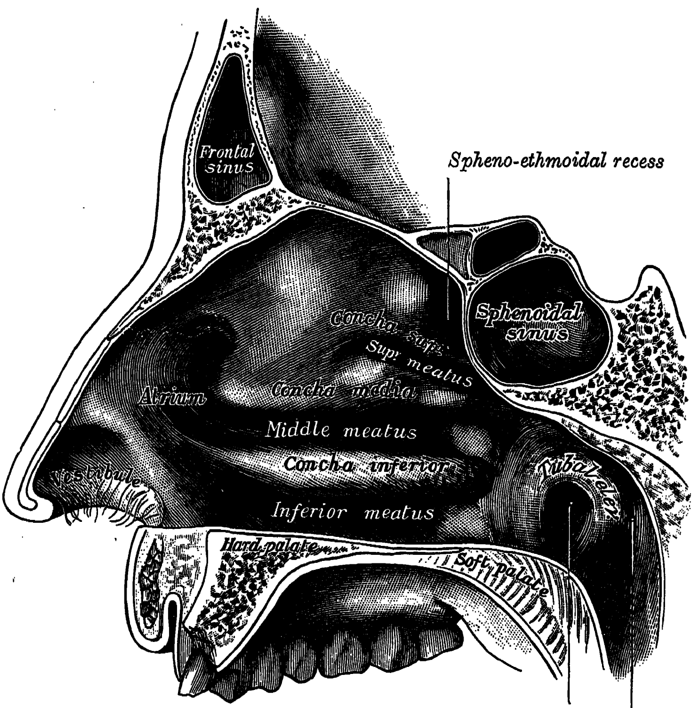
Inside the aperture of the nostril there is a slight dilatation, termed the *vestibule* (fig. 1007), bounded laterally by the ala and the lateral part of the lower nasal cartilage, and medially by the septal process of the same cartilage; it extends as a small recess towards the apex of the nose. The vestibule is lined with skin, and coarse hairs and sebaceous glands are found in its lower part; the hairs (vibrissæ) curve downwards and forwards to the naris, and tend to arrest the passage of foreign substances carried with the current of inspired air. The vestibule is limited above and behind by a curved elevation, named the *limen nasi*, along which the skin of the vestibule is continuous with the mucous membrane of the nasal cavity.

Each half of the nasal cavity, above and behind the vestibule, is divided into two parts: an *olfactory* region, limited to the superior nasal concha and

the opposed part of the septum, and a *respiratory* region, which comprises the rest of the cavity.

Lateral wall (figs. 1007, 1008).—The lateral wall is marked by three elevations, formed by the superior, middle and inferior nasal conchæ, and below and lateral to each concha by the corresponding nasal passage or meatus. Above the superior concha a triangular fossa, named the *spheno-ethmoidal recess*, receives the opening of the sphenoidal sinus. The *superior meatus* is a short oblique passage extending about half-way along the upper border of the middle concha; the posterior ethmoidal sinuses open, usually by two apertures, into the front part of this meatus. The *middle meatus*, deeper in front than behind, is below

FIG. 1007.—The lateral wall of the right half of the nasal cavity. Medial aspect.

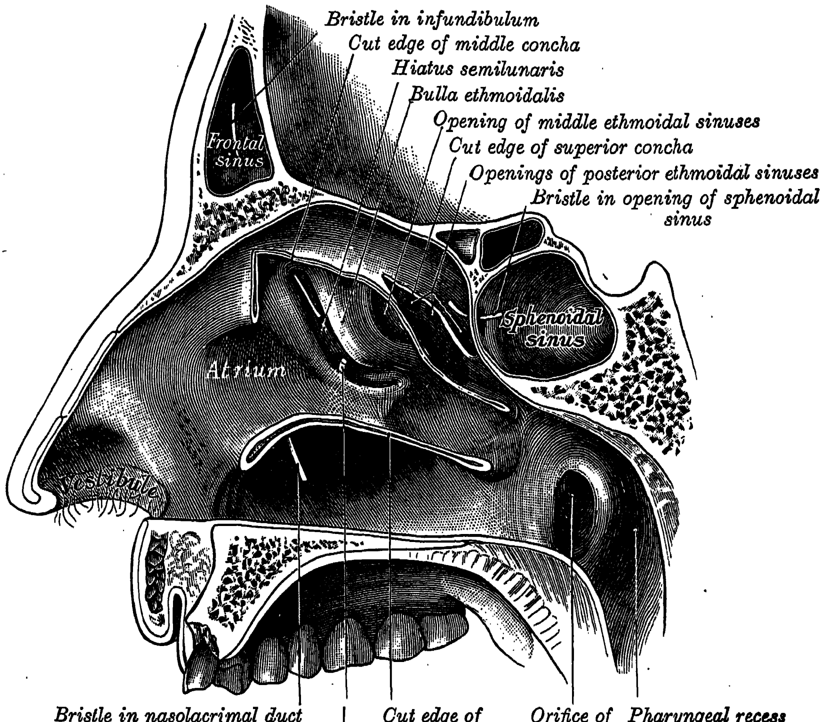


and lateral to the middle concha, and is continued anteriorly into a shallow depression situated above the vestibule and named the *atrium* of the middle meatus. Above the atrium an ill-defined curved ridge, termed the *agger nasi*, runs forwards and downwards from the upper end of the anterior free border of the middle concha; it is better developed in the new-born child than in the adult. When the middle concha is raised or removed the lateral wall of this meatus is displayed fully. A rounded elevation, termed the bulla ethmoidalis, and, below and extending upwards in front of it, a curved cleft, termed the hiatus semilunaris, form the principal features of this wall. The *bulla ethmoidalis* is caused by the bulging of the middle ethmoidal sinuses, which open on or immediately above it, and the size of the bulla varies with that of its contained sinuses. The *hiatus semilunaris*, which is bounded inferiorly by a sharp concave ridge produced by the uncinate process of the ethmoid bone, leads forwards and upwards into a curved channel, which is named the *ethmoidal infundibulum*. The anterior ethmoidal sinuses open into the front part of the infundibulum, which in rather more than 50 per cent. of subjects is continuous with the frontonasal duct or passage leading from the frontal sinus. The frontonasal duct frequently opens directly into the anterior end of the middle meatus. The opening of the maxillary sinus is situated below the bulla ethmoidalis, and is usually hidden by the flange-like lower (or medial) edge of

the hiatus semilunaris; in a coronal section of the nose this opening is seen to be placed near the roof of the sinus (fig. 1011). An accessory opening of the maxillary sinus is frequently present below and behind the hiatus semilunaris. The *inferior meatus* is below and lateral to the inferior nasal concha; the naso-lacrimal duct opens into this meatus under cover of the anterior part of the inferior concha.

Nasal septum (fig. 1005).—The nasal septum is frequently more or less deflected from the median plane, thus lessening the size of one half of the nasal cavity and increasing that of the other; ridges or spurs of bone sometimes

FIG. 1008.—The lateral wall of the right half of the nasal cavity; the three nasal conchæ have been removed.



project from the septum to one or other side. Immediately over the incisive canal at the lower edge of the cartilage of the septum a depression is sometimes seen; it points downwards and forwards, and occupies the position of a canal which connected the nasal with the buccal cavity in early fœtal life. In the septum close to this recess a minute orifice may be discerned; it leads backwards into a blind pouch—the rudimentary *vomeronasal organ of Jacobson*—which is supported by a strip of cartilage, named the *subvomerine* (vomeronasal) *cartilage*. This organ is well developed in many of the lower animals, where it apparently plays a part in the sense of smell, since it is supplied by twigs of the olfactory nerve and is lined with epithelium similar to that in the olfactory region of the nose.

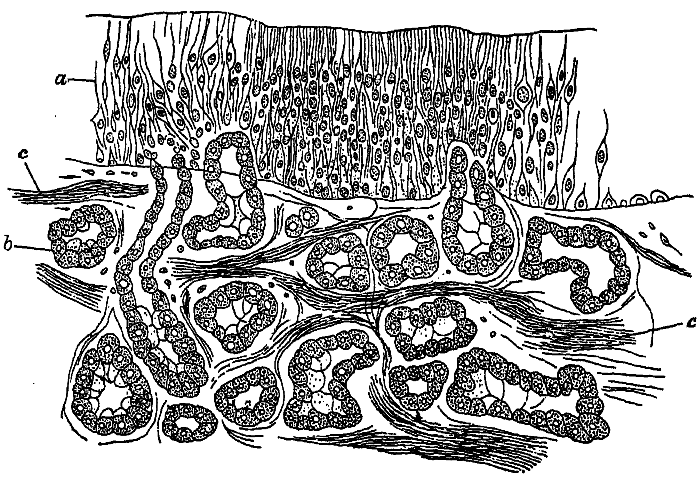
The *roof* of the nasal cavity is narrow from side to side, except at its posterior part, and may be divided, from behind forwards, into sphenoidal, ethmoidal and frontonasal parts, corresponding to the bones which enter into its formation (pp. 273 and 277). The ethmoidal part is almost horizontal, but the frontonasal and sphenoidal parts slope downwards and forwards and downwards and backwards, respectively. The cavity is therefore deepest where its roof is formed by the cribriform plate of the ethmoid bone.

The *floor* is concave from side to side, flat and almost horizontal antero-posteriorly; its anterior three-fourths are formed by the palatine process of the maxilla, its posterior one-fourth by the horizontal part of the palatine bone.

The **nasal mucous membrane** lines the nasal cavities with the exception of the vestibules, and is intimately adherent to the periosteum or perichondrium. It is continuous with the mucous membrane of the nasal part of the pharynx through the posterior nasal apertures; with the conjunctiva, through the naso-lacrimal duct and lacrimal canaliculi; and with the mucous membranes of the sphenoidal, ethmoidal, frontal and maxillary sinuses, through the openings of these sinuses.

The mucous membrane is thickest and most vascular over the nasal conchæ, especially at their extremities. It is also thick over the nasal septum, but very thin in the meatuses, on the floor of the nasal cavity, and in the various sinuses.

FIG. 1009.—A section through the olfactory mucous membranes. (Cadiat.)



a. Epithelium. *b.* Nasal glands. *c.* Nerve-bundles.

Owing to the thickness of the membrane, the nasal cavity is much narrower, and the middle and inferior nasal conchæ larger and more prominent than they appear in the skeleton; for the same reason the various apertures communicating with the meatuses are also considerably narrowed.

Structure of the mucous membrane.—The epithelium of the mucous membrane differs in its characteristics according to the functions of the part of the nose in which it is found. In the *respiratory region* it is columnar and ciliated. Goblet or mucous cells are interspersed among the columnar cells, while smaller pyramidal cells are found between the bases of the latter. Beneath the epithelium and its basement-membrane there is a fibrous layer infiltrated with lymph corpuscles, forming in many parts a diffuse adenoid tissue, and under this a nearly continuous layer of mucous and serous glands, the ducts of which open upon the surface. In the *olfactory region* (fig. 1009) the mucous membrane is yellowish in colour and the epithelial cells are of two kinds, supporting cells and olfactory cells. The *supporting cells* contain oval nuclei, which are situated in the deeper parts of the cells and constitute the zone of oval nuclei; the superficial part of each cell is columnar, and contains granules of yellow pigment, while its deep part is prolonged as a delicate process which ramifies, and communicates with similar processes from neighbouring cells so as to form a network in the mucous membrane. Lying between the deep processes of the supporting cells there are a number of bipolar nerve-cells—the *olfactory cells*—each consisting of a small amount of granular protoplasm with a large spherical nucleus, and possessing two processes; the superficial process runs between the columnar epithelial cells, and ends at the surface of the mucous membrane in one or more fine, hair-like processess, called the *olfactory hairs*; the deep or central process is frequently beaded, and is continued as an olfactory nerve-fibre (p. 1036). Beneath the epithelium, and extending through the thickness of the mucous membrane there is a layer of tubular, often branched, glands, termed the *nasal glands*, similar in structure to serous glands.

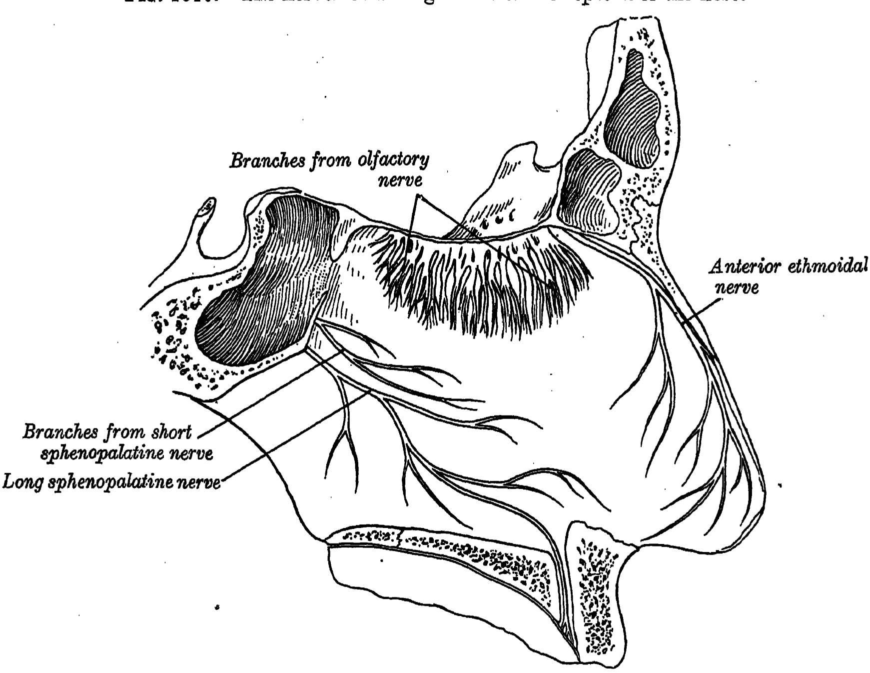
Vessels and Nerves.—The *arteries* of the nasal cavity are the anterior and posterior ethmoidal branches of the ophthalmic artery, which supply the ethmoidal and frontal

sinuses, and the roof of the nose; the sphenopalatine branch of the (internal) maxillary artery, which supplies the mucous membrane covering the conchæ, the meatuses, and septum; the septal ramus of the superior labial branch of the facial (external maxillary) artery; the infra-orbital and inferior dental branches of the maxillary artery, which supply the lining membrane of the maxillary sinus; and the pharyngeal branch of the same artery, which is distributed to the sphenoidal sinus. The ramifications of these vessels form a close plexiform network, beneath and in the substance of the mucous membrane.

The *veins* form a close cavernous plexus beneath the mucous membrane. This plexus is especially marked over the lower part of the septum and over the middle and inferior conchæ. Some of the veins open into the sphenopalatine vein; others join the anterior facial vein; some accompany the ethmoidal arteries, and end in the ophthalmic veins; a few communicate with the veins on the orbital surface of the frontal lobe of the brain, through the foramina in the cribriform plate of the ethmoid bone. When the foramen cæcum is patent it transmits a vein from the nasal cavity to the superior sagittal sinus.

The *lymph vessels* are described on p. 855.

FIG. 1010.—The nerves of the right side of the septum of the nose.



The *nerves* of ordinary sensation (figs. 943, 1010) are: the anterior ethmoidal branch of the nasociliary nerve, filaments from the anterior superior dental branch of the maxillary nerve, the nerve of the pterygoid canal, the long sphenopalatine (nasopalatine) nerve, the greater palatine (anterior palatine) and nasal branches of the sphenopalatine ganglion.

The anterior ethmoidal branch of the nasociliary nerve distributes filaments to the anterior parts of the septum and lateral wall. Filaments from the anterior superior dental nerve supply the inferior meatus and inferior concha. The nerve of the pterygoid canal supplies the upper and posterior parts of the septum, and superior concha; and the upper nasal branches from the sphenopalatine ganglion have a similar distribution. The long sphenopalatine (nasopalatine) nerve supplies the middle of the septum. The greater palatine nerve supplies the lower nasal branches to the middle and inferior conchæ.

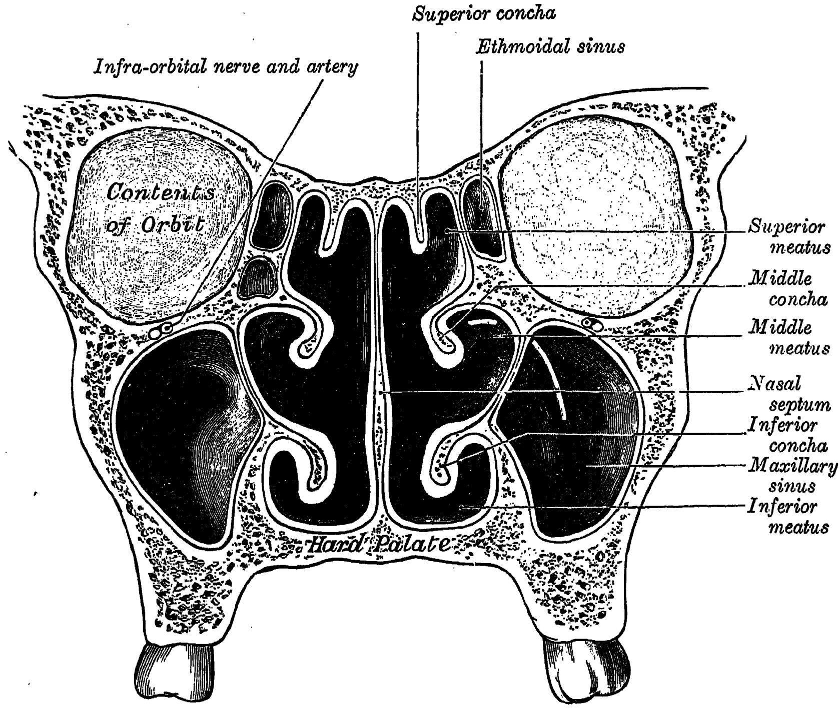
The *olfactory nerves* are distributed to the olfactory region. Their fibres arise from the bipolar olfactory cells and are destitute of medullary sheaths. They unite in fasciculi which cross one another in various directions, and thus give rise to the appearance of a plexus in the mucous membrane (fig. 1010) and then ascend in grooves or canals in the ethmoid bone; they pass into the skull through the foramina in the cribriform plate of the ethmoid and enter the under surface of the olfactory bulbs, in which they ramify and form synapses with the dendrites of the mitral cells (fig. 934). Closely associated with the olfactory nerves are the *nervi terminales* (p. 1037).

THE PARANASAL SINUSES (figs. 1006, 1007, 1008, 1011)

The paranasal sinuses are the frontal, ethmoidal, sphenoidal and maxillary; they vary in size and form in different individuals, and are lined with mucous membrane continuous with that of the nasal cavity.

The **frontal sinuses**, two in number, are situated behind the superciliary arches; they are rarely symmetrical, because the septum between them frequently deviates from the median plane. Their average measurements are as follows: height, 3·16 cm.; breadth, 2·58 cm.; depth from before backwards, 1·8 cm. Each opens into the anterior part of the corresponding middle meatus of the nose through the frontonasal duct, which traverses the anterior part of the labyrinth of the ethmoid. Small at birth, they are generally fairly well

FIG. 1011.—A coronal section through the nasal cavity.



developed between the seventh and eighth years, but only reach their full size after puberty.

The **ethmoidal sinuses** consist of numerous thin-walled cavities situated in the ethmoidal labyrinth, and completed by the frontal, maxillary, lacrimal, sphenoidal and palatine bones. They lie between the upper parts of the nasal cavity and the orbits, and are separated from the latter by the orbital plates of the ethmoid bone. On each side they are arranged in three groups—anterior, middle and posterior. The anterior and middle groups open into the middle meatus of the nose, the former by way of the ethmoidal infundibulum, the latter on or above the ethmoidal bulla. The posterior air-sinuses open into the superior meatus under cover of the superior nasal concha; sometimes one or more opens into the sphenoidal sinus. The ethmoidal sinuses begin to develop during fœtal life.

The **sphenoidal sinuses**, two in number, are placed behind the upper part of the nasal cavity, and are contained within the body of the sphenoid bone. They are related, above, to the optic chiasma, and the hypophysis cerebri; on each side, to the internal carotid artery and the cavernous sinus. They vary in size and shape, and, owing to the lateral displacement of the intervening septum,

are rarely symmetrical. Frequently one sinus is much the larger of the two and extends across the median plane behind the sinus of the opposite side. The following are their average measurements: vertical height, 2 cm.; transverse breadth, 1·8 cm.; anteroposterior depth, 2·1 cm. When exceptionally large they may extend into the roots of the pterygoid processes or greater wings, and may invade the basilar part of the occipital bone. Each sinus communicates with the spheno-ethmoidal recess by an aperture in the upper part of its anterior wall. They are present as minute cavities at birth, but their main development takes place after puberty.

The **maxillary sinuses**, which are the largest accessory air-sinuses of the nose, are pyramidal cavities in the bodies of the maxillæ. The base of each is formed by the lateral wall of the nasal cavity; the apex extends into the zygomatic process of the maxilla. The roof or orbital wall is frequently ridged by the infra-orbital canal, while the floor is formed by the alveolar process and is usually about 1·25 cm. below the level of the floor of the nose; several conical elevations corresponding with the roots of the first and second molar teeth project into the floor, which is sometimes perforated by one or more of these roots. The size of the maxillary sinus varies in different skulls, and even on the two sides of the same skull; when large, its apex may invade the zygomatic bone. The following measurements are those of an average-sized air-sinus: vertical height opposite the first molar tooth, 3·5 cm.; transverse breadth, 2·5 cm.; anteroposterior depth, 3·2 cm. It communicates with the lower part of the hiatus semilunaris through an opening in the anterosuperior part of its base (fig. 1011); a second orifice is frequently seen in, or immediately behind, the hiatus. The maxillary sinus appears as a shallow groove on the medial surface of the bone about the fourth month of fœtal life, but does not reach its full size until after the eruption of the permanent teeth.*

Applied Anatomy.—Instances of congenital deformity of the nose are occasionally met with, such as complete absence of the external nose, an aperture only being present, or perfect development on one side, and suppression or malformation on the other. Deformities which have been acquired are much more common, such as flattening of the nose, the result of syphilitic necrosis; or imperfect development of the nasal bones in cases of congenital syphilis; or a lateral deviation of the nose after fracture.

The septum of the nose may be displaced or may deviate from the median plane as a result of an injury or of some congenital defect. Sometimes the deviation may be so great that the septum may come into contact with the lateral wall of the nasal cavity, producing complete unilateral obstruction.

Suppuration in the paranasal sinuses of the nose is of frequent occurrence, and in connexion with this the situations at which the various sinuses normally communicate with the nasal cavity, are important: thus one finds they fall into two main groups: (1) anterior, opening into the middle meatus, and draining the maxillary, the frontal, and the anterior ethmoidal sinuses; and (2) posterior, opening into the superior meatus and spheno-ethmoidal recess, and draining the posterior ethmoidal and sphenoidal sinuses. Suppuration in the anterior group is the more common, and the pus can be seen running down over the anterior end of the inferior concha, whereas in the case of the posterior group, the pus does not come forwards, but runs back into the nasopharynx over the posterior end of the middle concha. Again, it is of importance to notice that the middle meatus is of such a form that pus running down from the frontal sinus is directed by the hiatus semilunaris into the opening of the maxillary sinus, so that the latter sinus may, in some cases, act as a secondary reservoir for pus discharged from the frontal sinus. All the paranasal sinuses can be and are infected from the nasal cavity, but it should be noted that in the case of the maxillary sinus, the infection is frequently conveyed in another way, and that is from the teeth. This sinus is the one most frequently the seat of chronic suppuration and it often requires drainage; this can be carried out by removing bone from the lateral wall of the inferior meatus of the nose. Simple drainage, however, is not usually sufficient, and more extensive operations have often to be performed.

The Organ of Sight

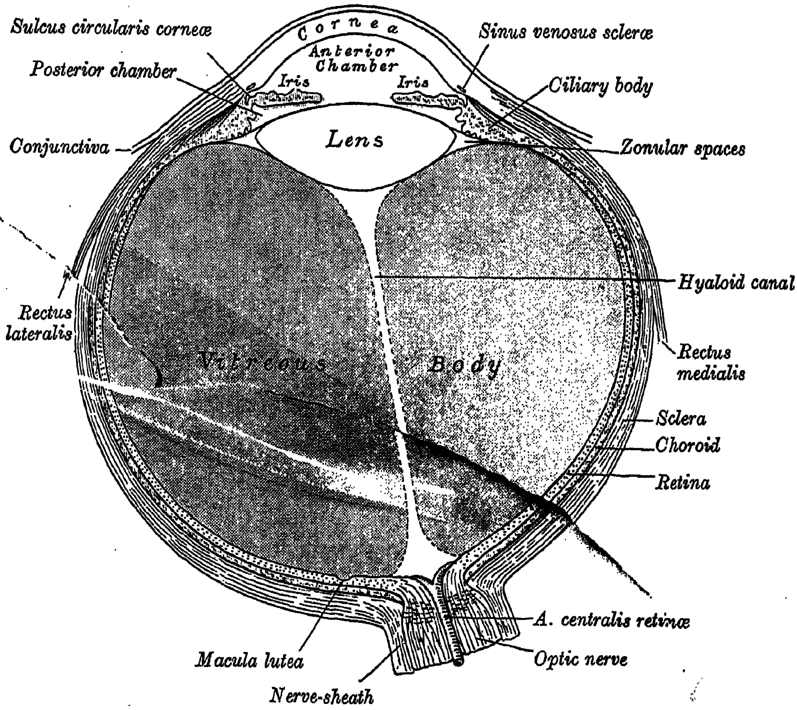
The eyeball (bulbus oculi) is the peripheral organ of sight, and is situated in the cavity of the orbit, the walls of which serve to protect it from injury. Certain accessory structures, viz. the muscles, fasciæ, eyebrows, eyelids,

* The measurements of the paranasal sinuses supplied in the text are those given by A. Logan Turner, *Accessory Sinuses of the Nose*, 1901.

conjunctiva and lacrimal apparatus, are intimately associated with the eyeball and will be described in the same section.

The eyeball is imbedded in the fat of the orbit, but is separated from it by a thin membranous sac, termed the *fascial sheath of the eyeball* (p. 1182). It is composed of segments of two spheres of different sizes. The anterior segment is one of a small sphere; it is transparent, and its arc forms about one-sixth of the circumference. It is more prominent than the posterior segment, which is one of a larger sphere, and is opaque, and forms about five-sixths of the whole circumference of the eyeball. The term *anterior pole* is applied to the central point of the anterior curvature of the eyeball, and that of *posterior pole* to the central point of its posterior curvature; a line joining the two poles forms the *optic axis*. The axes of the two eyeballs are nearly parallel, and therefore do not correspond with the axes of the orbits which are directed forwards and laterally. The optic nerves follow the direction of the axes of the orbits, and

Fig. 1012.—A horizontal section through the eyeball.



therefore are not parallel; *each nerve enters its eyeball 3 mm. to the nasal side of the posterior pole.* The vertical diameter (23·5 mm.) of the eyeball is rather less than the transverse and anteroposterior diameters (24 mm.); the anteroposterior diameter at birth is about 17·5 mm. and at puberty from 20 to 21 mm. In the female all three diameters are rather less than in the male.

The eyeball is composed of three coats, which enclose three refracting media.

The Coats of the Eye (fig. 1012)

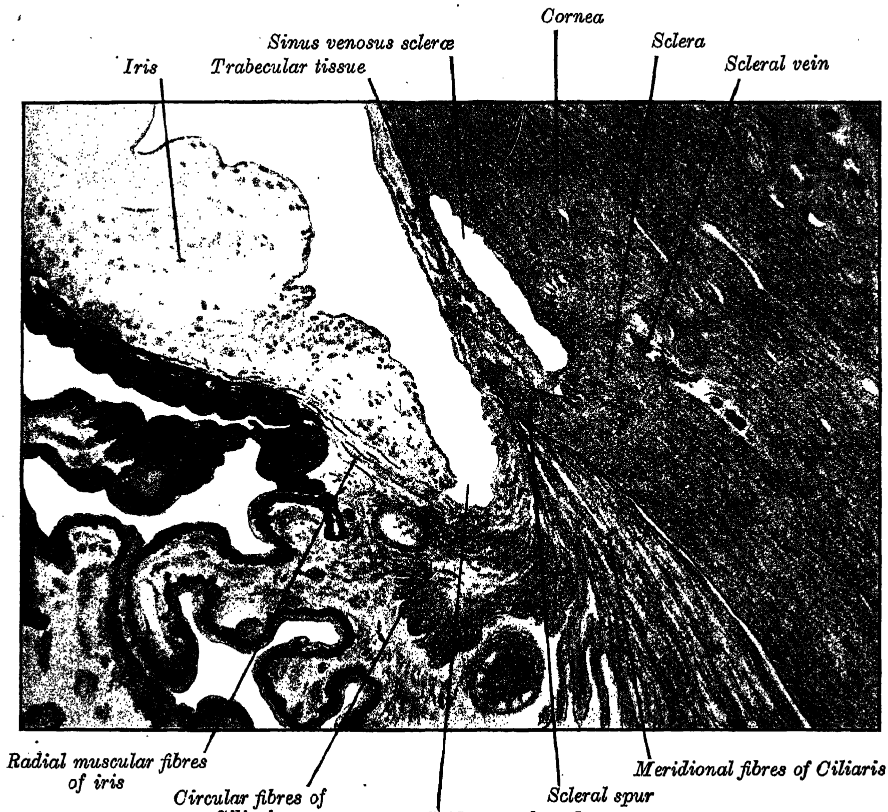
From without inwards the three coats are: (1) the fibrous coat, consisting of the *sclera* behind and the *cornea* in front; (2) the vascular, pigmented coat, comprising, from behind forwards, the *choroid, ciliary body* and *iris*; and (3) the nervous coat, termed the *retina*.

I. The Fibrous Coat

The fibrous coat of the eyeball (fig. 1012) consists of an opaque, posterior part, named the sclera, and a transparent, anterior part, named the cornea.

The **sclera**, so named from its density and hardness, is a firm membrane which serves to maintain the form of the eyeball. It is thickest (about 1 mm.) behind, near the entrance of the optic nerve, and thinnest (0·4 mm.) at a distance of about 6 mm. behind the sclerocorneal junction. Its *external surface* is white, and is in contact with the inner surface of the fascial sheath of the eyeball (p. 1182); it is smooth, except where the tendons of the orbital muscles are inserted into it; its anterior part is covered by the conjunctival membrane. Its *inner surface* is brown, and is marked by grooves in which the ciliary nerves and vessels are lodged; it is separated from the outer surface of the choroid by an extensive *perichoroidal space*, which is traversed by an exceedingly fine cellular tissue, termed the *suprachoroid lamina*. Behind, it is pierced by the optic nerve, and is continuous through the fibrous sheath of this nerve with the dura mater. Where the optic nerve pierces the sclera, the latter has the appearance of a cribriform plate and is named the *lamina cribrosa scleræ* (fig. 1022); the minute orifices in this lamina serve for the transmission of the nerve-bundles, and the fibrous septa between the orifices are continuous with the supporting tissue of the nerve. One opening, larger than the rest, and occupying the centre of the lamina, transmits the central artery and vein of the retina. Around the lamina cribrosa scleræ numerous small apertures are present for the transmission of the ciliary vessels and nerves, and about midway between these and the sclerocorneal junction there are four or five large apertures for the transmission of veins [*venæ vorticosæ*]. In front, the sclera is directly continuous with the cornea, the line of union being termed the *sclerocorneal junction*. In the substance of the sclera close to this junction is a circular canal, termed the *sinus venosus scleræ*. In a meridional section through the sclerocorneal junction, this sinus presents the appearance of a cleft, the outer wall of which consists

FIG. 1013.—A general view of the iridocorneal angle. Enlarged. (After Thomson.)



of the firm tissue of the sclera, while its inner wall is formed by a triangular mass of trabecular tissue (fig. 1013); the apex of the mass is directed forwards and is continuous with the posterior elastic lamina of the cornea. The sinus is lined with endothelium, and communicates internally with the anterior chamber of the eye, and is continuous externally with the anterior ciliary veins.

Structure.—The sclera is formed of white fibrous tissue intermixed with fine elastic fibres; flattened connective tissue corpuscles, some of which are pigmented, are contained in cell-spaces between the fibres. The fibres are aggregated into bundles, which are arranged chiefly in a longitudinal direction. Its *vessels* are not numerous; its capillaries are small, and unite at long and wide intervals. Its *nerves* are derived from the ciliary nerves, but their exact mode of ending is not known.

The **cornea** (fig. 1012) is the anterior, projecting and transparent part of the external coat; it is almost circular in outline, occasionally a little broader in the transverse than in the vertical direction. It is convex anteriorly, and projects as a flattened dome in front of the sclera. Its degree of curvature varies in different individuals, and in the same individual at different periods of life, being more pronounced in youth than in old age. The cornea is dense and of uniform thickness throughout; its posterior surface is perfectly circular in outline, and exceeds the anterior surface slightly in diameter. Immediately in front of the sclerocorneal junction the cornea bulges inwards as a thickened rim, and behind this rim there is a distinct furrow between the attachment of the iris and the sclerocorneal junction. This furrow has been named by Arthur Thomson * the *sulcus circularis corneæ*; it is bounded externally by the trabecular tissue already described as forming the inner wall of the sinus venosus scleræ. Between this tissue and the anterior surface of the attached margin of the iris there is an angular recess, named the *iridocorneal angle* (iridial angle) of the eye (fig. 1013). A projecting rim of scleral tissue which appears in a meridional section as a small triangular area, termed the *scleral spur*, is situated between the iridocorneal angle and the sinus venosus scleræ (fig. 1013). Its base is continuous with the inner surface of the sclera immediately to the outer side of the iridocorneal angle and its apex is directed forwards and inwards. The bundles of trabecular tissue just referred to are attached to the anterior sloping margin of this spur; the meridional fibres of the Ciliaris muscle arise from its posterior aspect.

Structure (fig. 1014).—The cornea consists from before backwards of four layers, viz.: (1) the corneal epithelium, continuous with that of the conjunctiva; (2) the substantia propria; (3) the posterior elastic lamina; and (4) the mesothelium of the anterior chamber.

The *corneal epithelium* covers the front of the cornea and consists of several layers of cells. The cells of the deepest layer are columnar; then follow two or three layers of polyhedral cells, the majority of which are prickle-cells similar to those found in the germinative zone of the epidermis (p. 1219). Lastly, there are three or four layers of squamous cells, with flattened nuclei.

The *substantia propria* is fibrous, tough, unyielding and perfectly transparent. It is composed of about sixty flattened, superimposed lamellæ. These lamellæ are made up of bundles of modified connective tissue, the fibres of which are continuous with those of the sclera. The fibres of each lamella are for the most part parallel with one another, but at right angles to those of adjacent lamellæ. Fibres, however, frequently pass from one lamella to the next.

Between the lamellæ there is a small amount of ground-substance, in which spaces are found, which are termed the *corneal spaces*. These are stellate in shape and communicate with one another by numerous offsets. Each contains a cell, named the *corneal corpuscle*, resembling in form the space in which it is lodged, but not entirely filling it.

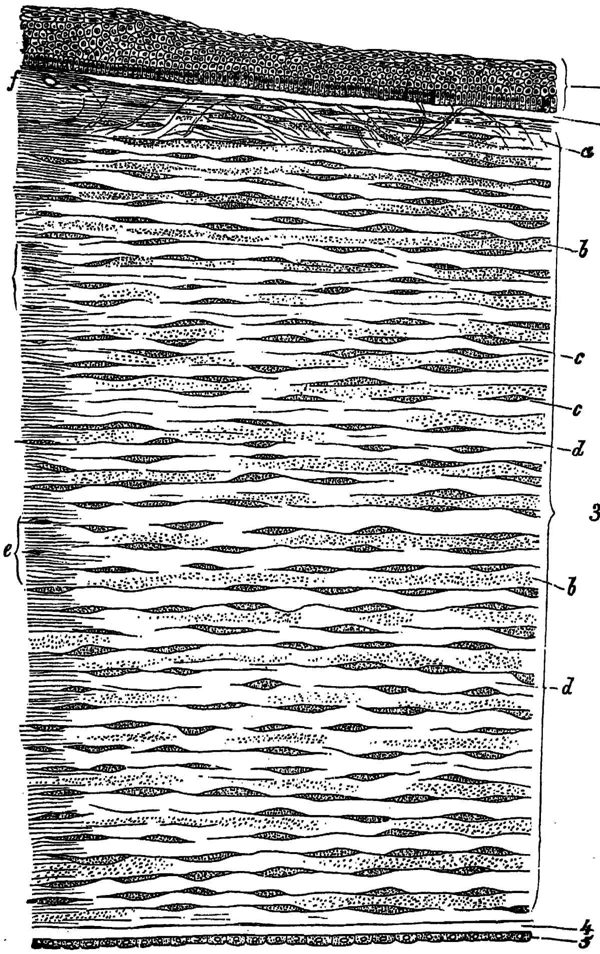
The layer immediately beneath the corneal epithelium presents certain characteristics which have led some anatomists to regard it as a distinct membrane, and it has been named the *anterior elastic lamina*. It consists of extremely closely interwoven fibrils, similar to those found in the substantia propria, but contains no corneal corpuscles.

The *posterior elastic lamina* covers the posterior surface of the substantia propria, and is a thin, elastic, transparent, homogeneous membrane, which is not rendered opaque by water, alcohol, or acids. When stripped from the substantia propria it curls up, and rolls upon itself, with the attached surface innermost.

* *Atlas of the Eye*, Clarendon Press, Oxford, 1912.

At the margin of the cornea the posterior elastic lamina breaks up into fibres which form the trabecular tissue on the inner wall of the sinus venosus scleræ (p. 1165); the spaces between the trabeculæ are termed the *spaces of the iridocorneal angle*; they communicate with the sinus venosus scleræ and with the anterior chamber. Some of the fibres of this trabecular tissue are continued into the substance of the iris, forming the *pectinate ligament of the iris*; others are connected with the fore-part of the sclera and choroid.

Fig. 1014.—A vertical section through the human cornea near its margin. Magnified. (Waldeyer.)



1. Epithelium. 2. Anterior elastic lamina. 3. Substantia propria. 4. Posterior elastic lamina. 5. Endothelium of the anterior chamber. *a.* Oblique fibres in the anterior layer of the substantia propria. *b.* Lamellæ the fibres of which are cut across producing a dotted appearance. *c.* Corneal corpuscles appearing fusiform in section. *d.* Lamellæ the fibres of which are cut longitudinally. *e.* Transition to the sclera, with more distinct fibrillation, and surmounted by a thicker epithelium. *f.* Small blood-vessels cut across near the margin of the cornea.

The *endothelium of the anterior chamber* covers the posterior surface of the posterior elastic lamina, is reflected on to the front of the iris, and also lines the spaces of the iridocorneal angle; it consists of a layer of polygonal, flattened, nucleated cells.

Vessels and Nerves.—The cornea is a non-vascular structure, the capillary vessels of the conjunctiva and sclera ending in loops at its circumference. Lymph vessels have not yet been demonstrated in it, but are probably represented by the channels in which the nerves run; these channels are lined by an endothelium. The *nerves* are numerous and are derived from the ciliary nerves. Around the periphery of the cornea they form an *annular plexus*, from which fibres enter the substantia propria. They lose their medullary sheaths and ramify throughout the substantia propria in a delicate network, and their terminal filaments form a firm and closer plexus beneath the corneal epithelium. This is termed the

subepithelial plexus, and from it fine, varicose fibrils are given off which ramify between the epithelial cells, forming an *intra-epithelial plexus*.

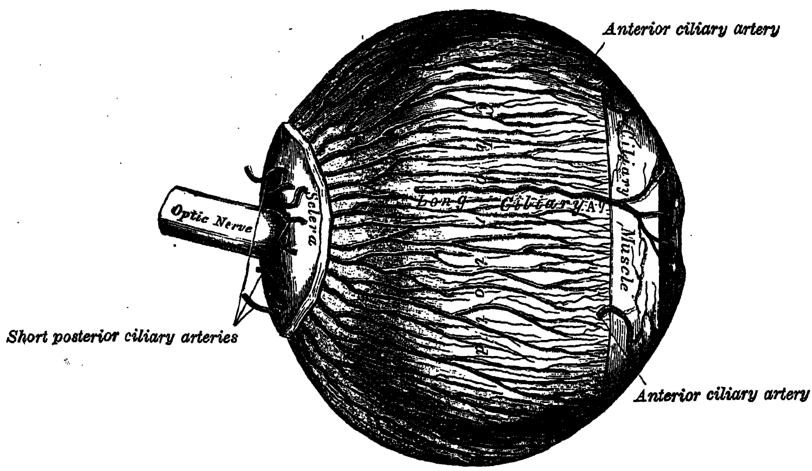
II. The Vascular Coat (figs. 1015 to 1020)

The vascular coat of the eye is formed from behind forwards by the choroid, the ciliary body and the iris.

The choroid covers the inner surface of the sclera, and extends as far forwards as the ora serrata of the retina. The ciliary body connects the choroid with the circumference of the iris. The iris is a circular diaphragm behind the cornea, and presents near its centre the rounded aperture of the *pupil*.

The choroid is a thin, highly vascular membrane, of a dark brown or chocolate colour, investing the posterior five-sixths of the eyeball; it is pierced

Fig. 1015.—The arteries of the choroid and iris. The greater part of the sclera has been removed. (Enlarged.)



behind by the optic nerve, and in this situation is firmly adherent to the sclera. It is thicker behind than in front. Its outer surface is loosely connected with the sclera by the suprachoroid lamina; its inner surface is attached to the pigmented layer of the retina.

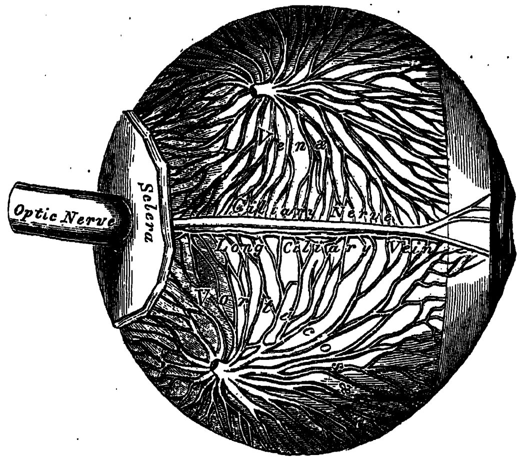
Structure.—The choroid consists mainly of a dense capillary plexus, and of small arteries and veins carrying blood to and from it. On its external surface there is a thin membrane, termed the *suprachoroid lamina*, which is composed of delicate non-vascular lamellæ, each lamella consisting of a network of fine elastic fibres, among which are branched pigment-cells. The spaces between the lamellæ are lined by mesothelium, and open freely into the perichoroidal lymph space, which, in its turn, communicates with the periscleral space at the points where the vessels and nerves are transmitted through the sclera.

The *choroid proper* lies internal to this lamina. It consists of two layers: an outer, composed of small arteries and veins, with pigment-cells interspersed between them; and an inner, consisting of a capillary plexus. The outer layer or *vascular lamina* consists, in part, of the larger branches of the short posterior ciliary arteries, which run forwards between the veins before they bend inwards to end in the capillaries, but is formed principally of veins, named, from their arrangement, the *venæ vorticosæ* (fig. 1016); these converge to four or five equidistant trunks, which pierce the sclera about midway between the sclero-corneal junction and the entrance of the optic nerve. Interspersed between the vessels there are dark star-shaped pigment-cells, the processes of which communicate with those of neighbouring cells, and form a delicate network or stroma, which loses its pigmentary character towards the inner surface of the choroid. The inner layer, or *choriocapillary lamina*, consists of an exceedingly fine capillary plexus, formed by the short ciliary vessels; the network is closer and finer in the posterior than in the anterior part of the choroid. About 1·25 cm. behind the cornea its meshes become larger, and are continuous with those of the ciliary processes. These laminæ are connected by a *stratum intermedium* consisting

of fine elastic fibres. On the inner surface of the choriocapillary lamina is a very thin, structureless, or faintly fibrous membrane, called the *basal lamina*; it is closely connected with the stroma of the choroid, and separates it from the pigmented layer of the retina.

Tapetum.—This name is often applied to the outer and posterior part of the choroid, which in many animals presents an iridescent appearance.

FIG. 1016.—The veins of the choroid. (Enlarged.)

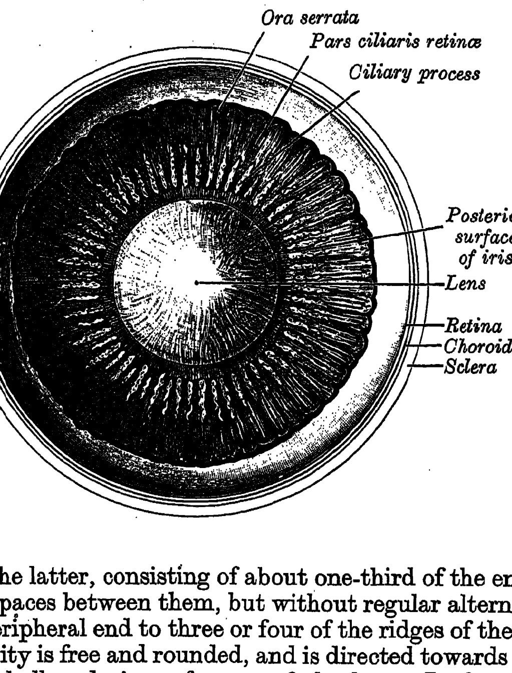


The **ciliary body** comprises the ciliary ring, the ciliary processes and the Ciliaris muscle.

The *ciliary ring* [orbiculus ciliaris] is a zone of about 4 mm. in width, directly continuous with the anterior part of the choroid; it presents numerous ridges arranged in a radial manner, but has no choriocapillary lamina.

The *ciliary processes* are formed by the inward folding of the various layers of the choroid (i.e. the choroid proper and the basal lamina), and are received between corresponding foldings of the suspensory ligament of the lens. They are arranged in a circle, and form a sort of frill behind the iris, round the margin of the lens (fig. 1017). They vary from sixty to eighty in number, lie side by side, and may be divided into large and small processes; the former are about

FIG. 1017.—The interior of the anterior half of the eyeball.



2·5 mm. long, and the latter, consisting of about one-third of the entire number, are situated in the spaces between them, but without regular alternation. Each is attached by its peripheral end to three or four of the ridges of the ciliary ring; the opposite extremity is free and rounded, and is directed towards the posterior chamber of the eyeball and circumference of the lens. In front, the ciliary processes are continuous with the periphery of the iris. Their posterior surfaces are connected with the suspensory ligament of the lens.

Structure.—The ciliary processes (figs. 1017, 1018) are similar in structure to the choroid, but the vessels are larger and have chiefly a longitudinal direction. Their posterior surfaces

are covered by the *ciliary part of the retina,* continued forwards from the nervous part of the retina, and consisting of an outer layer of cubical pigment-cells, and an inner layer of columnar cells which are not pigmented. In the stroma of the ciliary processes there are also stellate pigment-cells, but these are not so numerous as in the choroid itself.

The *Ciliaris muscle* consists of unstriped fibres; it forms a greyish, semi-transparent, circular band, about 6 mm. broad, on the outer surface of the fore-part of the choroid. It consists of meridional and circular fibres. The *meridional* fibres, much the more numerous, arise from the posterior margin of the scleral spur (p. 1166); they run backwards, and are attached to the ciliary processes and ring. The *circular* fibres are internal to the meridional ones, and in a meridional section appear as a triangular zone behind the irido-corneal angle and close to the circumference of the iris; they are well developed in hypermetropic, but are rudimentary or absent in myopic, eyes. The Ciliaris muscle is the chief agent in accommodation, i.e. in adjusting the eye to the vision of near objects. When it contracts, it draws forwards the ciliary processes, relaxes the suspensory ligament of the lens, and thus allows the lens to become more convex.

Fig. 1018.—The vessels of the choroid, ciliary processes and iris, of a child. (Arnold.) ×10.

a. Capillary network of the anterior part of the choroid, ending at *b*, the ora serrata. *c.* Arteries supplying the ciliary processes *d*, and passing into the iris *e*. *f.* The capillary network close to the pupillary margin of the iris.

The iris has received its name from the various colours it presents in different individuals. It is a thin, circular, contractile disc, suspended in the aqueous humour between the cornea and the lens, and perforated a little to the nasal side of its centre by the circular aperture of the *pupil.* Its periphery is continuous with the ciliary body, and is also connected with the posterior elastic lamina of the cornea by means of the pectinate ligament; its flattened surfaces look forwards and backwards, the anterior towards the cornea, the posterior towards the ciliary processes and lens. The iris divides the space between the lens and the cornea into an anterior and a posterior chamber (fig. 1012). The *anterior chamber* of the eye is bounded in front by the posterior surface of the cornea, behind by the front of the iris, and, opposite the pupil, by the central part of the front of the lens. The *posterior chamber* is a narrow chink behind the iris, and in front of the lens and its suspensory ligament. In the adult the two chambers communicate through the pupil, but in the fœtus up to the seventh month they are separated by the *pupillary membrane* (p. 1171).

The colour of the iris is produced by the reflection of light from dark pigment-cells underlying a translucent tissue, and is therefore determined by the amount of the pigment and its distribution throughout the texture of the iris. The number and the situation of the pigment-cells differ in different irises. In the albino pigment is absent; in the various shades of blue eyes the pigment-cells are confined to the posterior surface of the iris, whereas in grey, brown, and black eyes pigment is found also in the cells of the stroma and in those of the endothelium on the front of the iris.

Structure.—The iris is composed of the following structures:

1. In the front there is a layer of flattened endothelial cells, placed on a delicate hyaline basement-membrane. This layer of cells is continuous with the endothelium covering the posterior elastic lamina of the cornea, and in individuals with dark-coloured irises the cells contain pigment-granules.

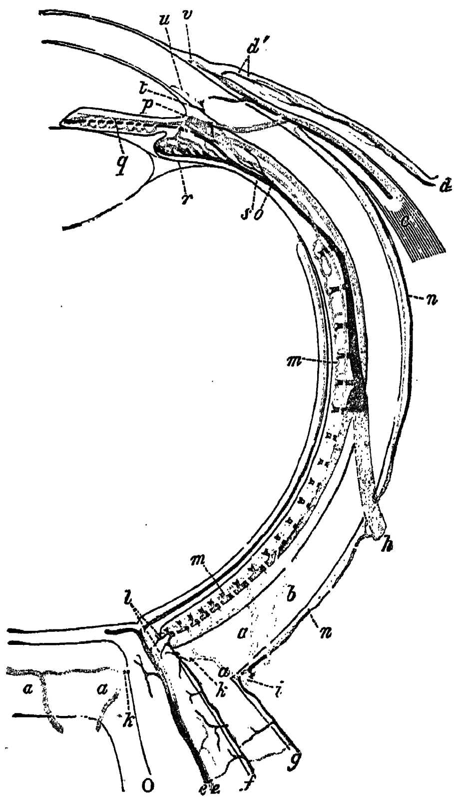
2. The *stroma* of the iris consists of connective tissue fibres and cells. A few fibres at the circumference of the iris have a circular direction; but the majority are arranged radially, forming, by their interlacement, delicate meshes, in which the vessels and nerves are contained. Interspersed between the bundles of connective tissue there

are numerous branched cells with fine processes. In dark eyes many of these cells contain pigment-granules, but in blue eyes and the eyes of albinos they are unpigmented.

3. The *muscular fibres* are involuntary, and consist of circular and radiating fibres. The *circular fibres* form the Sphincter pupillæ; they are arranged in a band about 1 mm. wide which surrounds the margin of the pupil, towards the posterior surface of the iris; those near the free margin of the band are closely aggregated; those near the periphery are somewhat separated and form incomplete circles. The *radiating fibres* form the Dilatator pupillæ and lie close to the posterior surface of the iris; they converge from the circumference towards the centre, and blend with the circular fibres near the margin of the pupil.

4. The posterior surface of the iris is of a deep purple tint, being covered by two layers of pigmented epithelial cells, continuous at the periphery of the iris with the ciliary part of the retina. This pigmented epithelium is often named the *pars iridica retinæ.*

Fig. 1019.—A diagrammatic representation of the course of the vessels of the eye. Horizontal section. (Leber.) Arteries and capillaries *red*; veins *blue*.



O. Entrance of optic nerve. *a*. Short posterior ciliary arteries. *b*. Long posterior ciliary arteries. *c*. Anterior ciliary vessels. *d*. Posterior conjunctival vessels. *d*. Anterior conjunctival vessels. *e*. Central vessels of the retina. *f*. Vessels of the inner sheath of the optic nerve. *g*. Vessels of the outer sheath. *h*. Vorticose veins. *i*. Short posterior ciliary vein. *k*. Branches of the short posterior ciliary arteries to the optic nerve. *l*. Anastomosis of choroidal vessels with those of optic nerve. *m*. Choriocapillaris. *n*. Episcleral vessels. *o*. Recurrent artery of the choroid. *p*. Circulus arteriosus major (in section). *q*. Vessels of iris. *r*. Vessels of ciliary process. *s*. Branch from ciliary muscle to vorticose vein. *t*. Branch from ciliary muscle to anterior ciliary vein. *u*. Sinus venosus scleræ. *v*. Capillary loop at margin of cornea.

Vessels and Nerves.—The *arteries of the iris* are derived from the long posterior and the anterior ciliary arteries, and from the vessels of the ciliary processes. Each of the two long ciliary arteries, on reaching the attached margin of the iris, divides into an upper and a lower branch; these anastomose with corresponding branches of the artery from the opposite side and with the anterior ciliary arteries, and form a vascular circle (*circulus arteriosus major*). From this circle vessels converge to the free margin of the iris, and there communicate and form a second circle (*circulus arteriosus minor*) (fig. 1020).

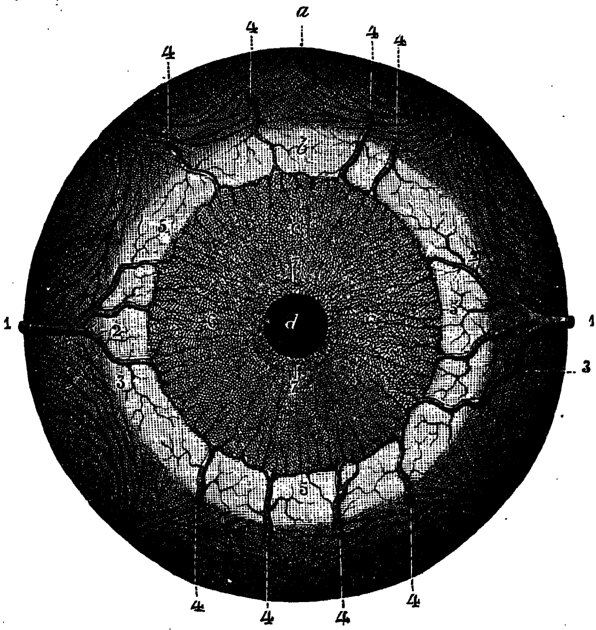
The *nerves of the choroid and iris* are the long and short ciliary nerves; the former are branches of the nasociliary nerve, the latter of the ciliary ganglion. They pierce the sclera around the entrance of the optic nerve, run forwards in the perichoroidal space, and supply the blood-vessels of the choroid and the ciliary muscle. After reaching the iris they form a plexus around its attached margin; from this non-medullated fibres are derived which end in the Sphincter and Dilatator pupillæ. Other fibres from the plexus end in a network on the anterior surface of the iris. The fibres derived through the motor (parasympathetic) root of the ciliary ganglion from the oculomotor nerve supply the Sphincter pupillæ and the Ciliaris muscle; the sympathetic fibres in the long ciliary nerves supply the Dilatator pupillæ.

Membrana pupillaris.—In the fœtus, the pupil is closed by a delicate, vascular membrane, termed the *pupillary membrane* (p. 128). The vessels of this membrane are partly derived from those of the margin of the iris and partly from those of the capsule of the lens; they end in loops a short distance from the centre of the membrane, which is thus left free from blood-vessels. About the sixth month of fœtal life the membrane begins to disappear by absorption from the centre towards the circumference, and at birth only a few fragments are present; in exceptional cases it persists.

III. The Retina (fig. 1012)

The retina is a delicate, nervous membrane, which is specially adapted for the reception of light stimuli. Its outer surface is in contact with the choroid; its inner with the hyaloid membrane of the vitreous body. Posteriorly it is continuous with the optic nerve; it gradually diminishes in thickness from behind forwards and, just behind the ciliary body, it presents a jagged margin named the *ora serrata*. Here the nervous tissues of the retina end, but a thin prolongation of the membrane extends forwards over the back of the ciliary processes and iris, forming the *ciliary* and *iridial parts of the retina*. This forward prolongation consists of the pigmented layer of the retina together with

Fig. 1020.—The iris, viewed from in front, with its circulus arteriosus major and circulus arteriosus minor. (Testut.)



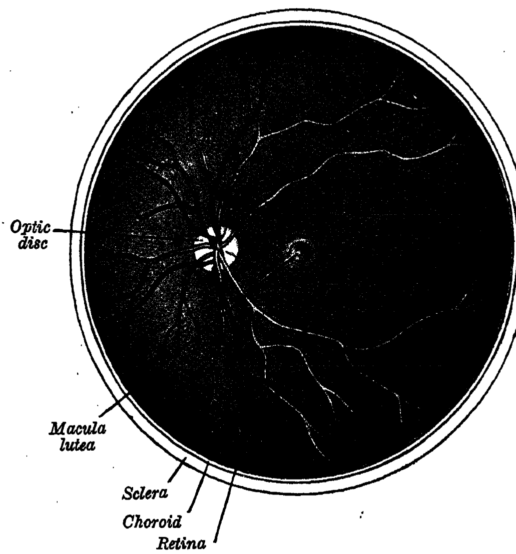
a. Choroid. *b*. Ciliaris muscle. *c*. Iris. *d*. Pupil. 1 and 1'. The two long ciliary arteries with 2, their ascending branches of bifurcation; 3, their descending branches of bifurcation. 4. The anterior ciliary arteries. 5. Circulus major; 6, its branches radiating through the iris. 7. Circulus minor around the pupil.

a stratum of columnar epithelium; in the pars iridica retinæ both layers of epithelium are cubical and pigmented. The retina is soft, translucent, and of a purple tint in the fresh state, owing to the presence of a colouring material, named *rhodopsin*, or *visual purple*; but it soon becomes clouded, opaque, and bleached when exposed to light. Near the centre of the posterior part of the retina there is an oval, yellowish area, named the *macula lutea*, where the visual sense is most perfect; it shows a central depression, termed the *fovea centralis* (fig. 1021). At the fovea centralis the retina is exceedingly thin, and the dark colour of the choroid is distinctly seen through it. About 3 mm. to the nasal side of the macula lutea the optic nerve pierces the retina at the *optic disc*, which has a diameter of about 1·5 mm. The circumference of the disc is slightly raised, while the central part presents a depression. The centre of the disc is pierced by the central artery and vein of the retina (fig. 1012). The optic disc is insensitive to light, and is termed the 'blind spot.'

Structure (figs. 1023, 1024).— The retina consists of an outer pigmented layer and an inner nervous stratum or retina proper.

The **pigmented layer** is a single stratum of cells. When viewed from the outer surface these cells are smooth and hexagonal in shape; when seen in section each cell consists of an outer non-pigmented part containing a large oval nucleus, and an inner pigmented portion which extends as a series of straight thread-like processes between the rods (fig. 1024), the amount of pigment between the rods being greater when the eye has been exposed to light. In the eyes of albinos the cells of the layer are destitute of pigment.

Fig. 1021.—The interior of the posterior half of the left eyeball.



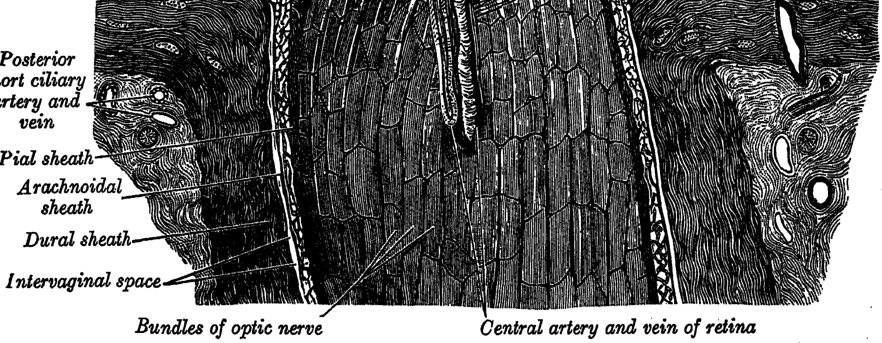
The veins are darker in appearance than the arteries.

Retina proper.—The nervous structures of the retina proper are supported by a series of non-nervous, or sustentacular, fibres, and, when examined microscopically by means of sections made perpendicular to the surface of the retina, are found to comprise seven layers, named from within outwards as follows:

1. Stratum opticum.
2. Ganglionic layer.
3. Inner plexiform layer.
4. Inner nuclear layer.
5. Outer plexiform layer.
6. Outer nuclear layer.
7. Layer of rods and cones.

1. The *stratum opticum* or *layer of nerve-fibres* is formed by the expansion of the fibres of the optic nerve; it is thickest near the optic disc, gradually diminishing towards the ora serrata. As the nerve-fibres pass through the lamina cribrosa scleræ (p. 1165), they lose

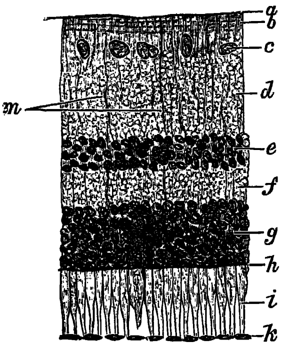
Fig. 1022.—A horizontal section through the terminal portion of the optic nerve and its entrance into the eyeball. (From Toldt's *Atlas*, published by Messrs. Rebman, Ltd., London.)



their medullary sheaths and are continued onwards through the choroid and retina as simple axis-cylinders. When they reach the internal surface of the retina they radiate from their point of entrance over this surface, grouped in bundles which communicate with

one another and form an intricate network. Most of the fibres are centripetal and are the continuations of the axis-cylinder processes of the cells of the ganglionic layer, but a few are centrifugal; these originate in the brain and ramify in the inner plexiform and inner nuclear layers of the retina, where they end.

Fig. 1023.—A section through the retina. (Magnified.)



a. Membrana limitans interna. *b.* Stratum opticum. *c.* Ganglionic layer. *d.* Inner plexiform layer. *e.* Inner nuclear layer. *f.* Outer plexiform layer. *g.* Outer nuclear layer. *h.* Membrana limitans externa. *i.* Layer of rods and cones. *k.* Pigmented layer. *m.* Fibres of Müller.

2. The *ganglionic layer* consists of a single layer of large nerve-cells, except in the macula lutea, where there are several strata. The cells are somewhat flask-shaped, the rounded internal surface of each resting on, and sending an axon into, the stratum opticum. From the opposite end numerous dendrites extend into the inner plexiform layer, where they form flattened arborisations at different levels. The ganglion-cells vary much in size, and the dendrites of the smaller ones as a rule arborise in the inner plexiform layer as soon as they enter it; while those of the larger cells ramify close to the inner nuclear layer.

3. The *inner plexiform layer* is made up of a dense reticulum of minute fibrils formed by the interlacement of the dendrites of the ganglion-cells with the processes of the cells of the inner nuclear layer; within this reticulum a few branched cells are imbedded.

4. The *inner nuclear layer* is made up of a number of closely packed cells, of which there are three varieties, viz. bipolar cells, horizontal cells and amacrine cells.

The *bipolar cells,* by far the most numerous, are divisible into rod- and cone-bipolars. They are round or oval in shape, and each is prolonged into an inner and an outer process. The inner processes of the *rod-bipolars* run through the inner plexiform layer and arborise around the outer parts of the cell-bodies of the ganglionic layer; their outer processes end in the outer plexiform layer in tufts of fibrils around the button-like ends of the inner processes of the rod-granules. The inner processes of the *cone-bipolars* ramify in the inner plexiform layer in contact with the dendrites of the ganglionic cells; their outer processes pass into the outer plexiform layer, where they divide and form arborisations with the expanded foot-plate of the inner processes of the cone-granules.

The *horizontal cells* lie in the outer part of the inner nuclear layer and possess somewhat flattened cell-bodies. Their dendrites divide into numerous branches in the outer plexiform layer, while their axons run horizontally for some distance and finally ramify in the same layer.

The *amacrine cells* are placed in the inner part of the inner nuclear layer, and were so named under the supposition that they were destitute of axons. It is now known that some, at least, possess axons. Their dendrites undergo extensive ramification in the inner plexiform layer.

5. The *outer plexiform layer* is much thinner than the inner; but, like it, consists of a dense network of minute fibrils derived from the processes of the horizontal cells, and the outer processes of the rod- and cone-bipolar cells of the preceding layer, which arborise around the enlarged ends of the rod-fibres and the branched foot-plate of the cone-fibres.

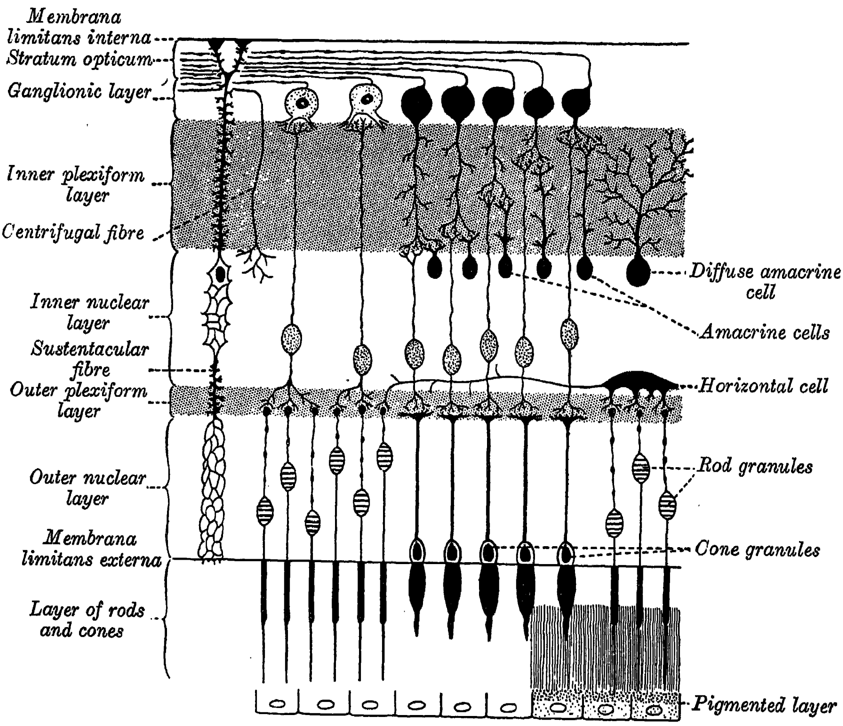
6. The *outer nuclear layer.*—Like the inner nuclear layer, this contains several strata of oval cells; they are of two kinds, viz. rod-granules and cone-granules, the former being connected with the rods, the latter with the cones, of the next layer. The *rod-granules* are much the more numerous, and are placed at different levels throughout the layer ; in some animals they present a cross-striped appearance. A fine process is prolonged from each extremity of each cell; the outer process is continuous with a rod of the layer of rods and cones ; the inner process ends in the outer plexiform layer in an enlarged extremity and is imbedded in the tuft into which the outer processes of the rod-bipolar cells break up ; in its course it presents numerous varicosities. The *cone-granules,* fewer in number than the rod-granules, are placed close to the membrana limitans externa, through which they are continuous with the cones of the layer of rods and cones. Each contains a spheroidal nucleus which almost completely fills the granule. From the inner extremity of each cone-granule a thick process passes into the outer plexiform layer, and there expands into a pyramidal enlargement or foot-plate, from which are given off numerous fine fibrils that come in contact with the outer processes of the cone-bipolars.

7. The *layer of rods and cones.*—The elements composing this layer are of two kinds, *rods* and *cones,* the former being much more numerous than the latter except in the macula lutea. The *rods* are cylindrical, of nearly uniform thickness, and are arranged perpendicularly to the surface. Each rod consists of two segments, an outer and an inner, of about equal lengths. The segments differ from each other as regards refraction and in their behaviour towards colouring reagents ; the inner segment is stained by carmine, iodine,

etc.; the outer segment is not stained by these reagents, but is coloured yellowish-brown by osmic acid. The outer segment is marked by transverse striæ, and tends to break up into a number of thin superimposed discs; it also exhibits faint longitudinal markings. The inner part of the inner segment is indistinctly granular; the outer part is longitudinally striated, being composed of fine, highly refracting fibrils. The visual purple or rhodopsin is found only in the outer segments of the rods.

The *cones* are conical, their broad ends resting upon the membrana limitans externa, the pointed extremities being turned to the choroid. Like the rods, each is made up of two segments, outer and inner; the outer segment is a short conical process, which, like the outer segment of a rod, exhibits transverse striæ. The inner segment resembles the inner segment of a rod in structure, presenting an outer striated and an inner granular part, but differs from it in size and shape, being flask-shaped. The optical characters of the two portions are identical with those of the rods.

FIG. 1024.—A plan of the retinal neurones. (After Ramón y Cajal.)



Supporting framework of the retina.—The nervous layers of the retina are connected together by a supporting framework, formed by the *sustentacular fibres* (fig. 1024); these fibres pass through all the nervous layers, except that of the rods and cones. Each fibre begins on the inner surface of the retina by an expanded, often forked, base, which sometimes contains a spheroidal body, staining deeply with hæmatoxylin; the edges of the bases of adjoining fibres are united to form the *membrana limitans interna*. As the sustentacular fibres pass through the stratum opticum and the ganglionic layer they send off a few lateral branches; in the inner nuclear layer they give off numerous lateral processes for the support of the bipolar cells, while in the outer nuclear layer they form a network and unite to form the *membrana limitans externa* at the bases of the rods and cones. At the level of the inner nuclear layer each sustentacular fibre contains a clear oval nucleus.

Structure of the macula lutea and fovea centralis.—At the fovea centralis there are no rods, and the cones are longer and thinner than in other parts of the retina. The nerve-fibre layer disappears at the margin of the fovea, and the other retinal layers are extremely thin. The pigment-cells are large and well-marked. At the circumference of the fovea the retina rapidly increases in thickness, so that this part of the macula lutea has a greater depth than any other part of the retina. All the layers are involved in this increase, but especially the ganglionic layer, in which the cells are six to eight deep. The yellow colour

of the macula seems to imbue all the layers except that of the rods and cones; it is deepest towards the centre of the macula, and does not appear to be due to pigment-cells, but simply to a staining of the constituent parts.

At the *ora serrata* the nervous layers of the retina end abruptly, and the retina is continued onwards as a single layer of columnar cells along with the pigmented layer. This double layer is known as the *ciliary part of the retina*, and can be traced forwards from the ciliary processes on to the back of the iris, where it is termed the *iridial part of the retina* (p. 1172).

The *central artery of the retina* (fig. 1021) and its accompanying vein pierce the lower and medial surface of the optic nerve, and enter the bulb of the eye at the centre of the optic disc. The artery immediately bifurcates into an upper and a lower branch, and each of these again divides into a nasal and a temporal branch, which at first run between the hyaloid membrane and the nervous layer; but they soon enter the latter, and pass forwards, dividing dichotomously. From those branches a minute capillary plexus is given off, which does not extend beyond the inner nuclear layer. The macula receives two small branches (superior and inferior macular arteries) from the temporal branches, and small twigs directly from the central artery; these do not, however, reach as far as the fovea centralis, which has no blood-vessels. The branches of the arteria centralis retinæ do not anastomose with each other—in other words, they are terminal arteries. In the fœtus, a small vessel, termed the hyaloid artery, passes forwards as a continuation of the central artery of the retina through the vitreous humour to the posterior surface of the capsule of the lens.

The Refracting Media of the Eye

The refracting media of the eye are the aqueous humour, the vitreous body and the lens.

I. The Aqueous Humour

The **aqueous humour** fills the anterior and posterior chambers of the eyeball (fig. 1012). It is small in quantity, has an alkaline reaction, and is a dilute saline solution, derived from the blood plasma. It is secreted into the posterior chamber from the vessels of the iris and the ciliary processes. It escapes from the iridocorneal angle of the anterior chamber into the anterior ciliary veins, through the spaces of the angle and the sinus venosus scleræ.

Applied Anatomy.—Interference with the resorption of the aqueous humour into the sinus venosus scleræ results in increase of the intra-ocular tension—the condition known as glaucoma. The optic disc becomes cupped and, owing to degenerative changes in the nervous elements of the retina produced by pressure, blindness eventually results. The operation of iridectomy, performed in the earlier stages of the disease, re-establishes the flow of the aqueous humour from the posterior chamber to the anterior, in cases where the disease is due to adhesions between the iris and the lens.

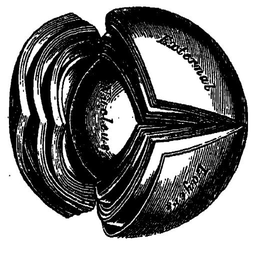
II. The Vitreous Body

The **vitreous body** (fig. 1012) occupies about four-fifths of the eyeball. It fills the concavity of the retina, and is hollowed in front, forming a deep concavity, termed the *hyaloid fossa*, for the reception of the lens. It is transparent, of the consistence of thin jelly, and is enclosed in a delicate transparent membrane, named the *hyaloid membrane*. It has been supposed by Hannover, that from the surface of the hyaloid membrane numerous thin lamellæ are prolonged inwards in a radiating manner, forming spaces in which the jelly is contained. In the adult, these lamellæ cannot be detected even after careful microscopical examination in the fresh state, but in preparations hardened in weak chromic acid it is possible to make out a distinct lamellation at the periphery of the vitreous body. The *hyaloid canal*, which is filled with lymph and lined by a prolongation of the hyaloid membrane, runs forward through the vitreous body from the entrance of the optic nerve to the posterior surface of the lens. In the embryonic vitreous body this canal conveyed the hyaloid artery from the central artery of the retina to the back of the lens.

The vitreous body consists of 98·6 per cent. water, with some salts and a little protein.

The *hyaloid membrane* envelops the vitreous body. The portion in front of the ora serrata is thickened by the accession of radial fibres and is termed the *zonula ciliaris*. Here it presents a series of radially arranged furrows, in which the ciliary processes are accommodated and to which they adhere, as is shown by the fact that when they are removed some of their pigment remains attached to the zonula. The zonula ciliaris splits into two layers, one of which is thin and lines the hyaloid fossa of the vitreous body; the other, named the *suspensory ligament of the lens*, is thicker and passes over the ciliary body to be attached to the capsule of the lens a short distance in front of its equator. Scattered and delicate fibres are also attached to the region of the equator itself. This ligament retains the lens in position, and is relaxed by the contraction of the meridional fibres of the Ciliary muscle, so that the lens is allowed to become more convex. Behind the suspensory ligament there is a sacculated canal, named the *spatia zonularia*, which encircles the equator of the lens; it can be easily inflated through a fine blowpipe inserted under the suspensory ligament.

Fig. 1025.—The lens, hardened and divided. (Enlarged.)



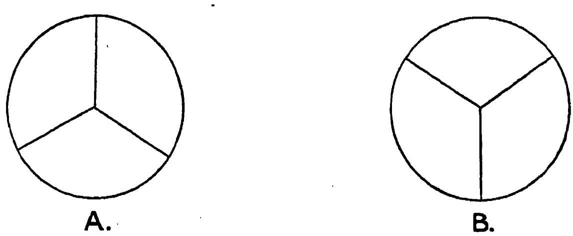
No blood-vessels penetrate the vitreous body; so that its nutrition must be carried on by the vessels of the retina and ciliary processes, situated upon its exterior.

III. The Lens

The lens (fig. 1012), enclosed in its capsule, is situated immediately behind the iris, in front of the vitreous body, and is encircled by the ciliary processes, which slightly overlap its margin.

The *capsule of the lens* is a transparent, structureless membrane which closely surrounds the lens, and is thicker in front than behind. It is brittle but highly elastic, and when it is ruptured the edges roll up with the outer surface innermost. The lens rests, behind, in the hyaloid fossa on the fore-part of the vitreous body; in front, it is in contact with the free border of the iris, but recedes from it at the circumference, thus forming the posterior chamber of the eye; it is retained in its position chiefly by the suspensory ligament already described.

Fig. 1026.—A diagram showing the direction and arrangement of the radiating lines on the fœtal lens. a. On the back. b. On the front.

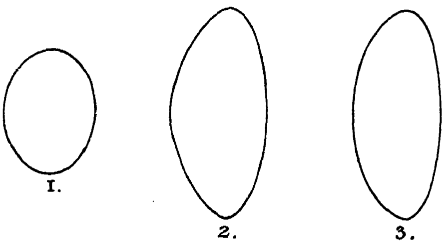


The *lens* is a transparent, biconvex body, the convexity of its anterior being less than that of its posterior surface. The central points of these surfaces are termed respectively the *anterior* and *posterior poles*; a line connecting the poles constitutes the *axis* of the lens, while the marginal circumference is termed the *equator*.

Structure.—The lens is made up of soft cortical substance and a firm, central part, the so-called nucleus (fig. 1025). Faint sutural lines [radii lentis] radiate from the poles to the

equator. In the adult there may be six or more of these lines, but in the fœtus there are only three, and these diverge in a Y-shaped manner at angles of 120°; on the anterior surface the Y is upright (fig. 1026, B); on the posterior surface the Y is inverted (fig. 1026, A).* These lines correspond with the free edges of septa composed of an amorphous substance, which dip into the substance of the lens. When the lens has been hardened it is seen to consist of a series of concentrically arranged laminæ, each of which is interrupted at the septa referred to. Each lamina is built up of a number of ribbon-like lens-fibres, the edges of which are more or less serrated—the serrations fitting between those of neighbouring fibres, while the ends of the fibres come into apposition at the septa. The fibres run in a curved manner from the septa on the anterior surface to those on the posterior surface. No fibres pass from pole to pole; they are arranged in such a way that those which begin near the pole on

FIG. 1027.—Profile views of the lens at different periods of life.

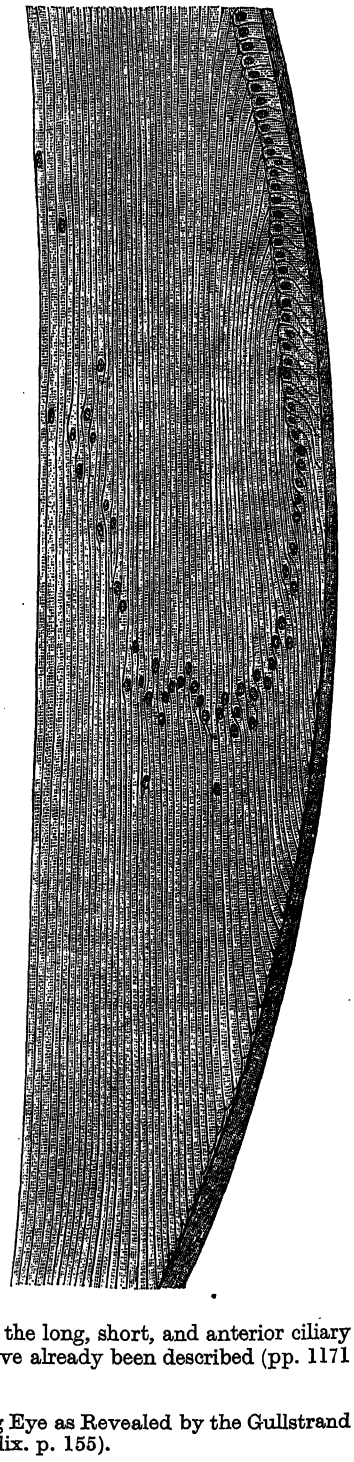


1. In the fœtus. 2. In adult life. 3. In old age.

one surface of the lens end near the peripheral extremity of the plane on the other, and vice versa. The fibres of the outer layers of the lens are nucleated, and together form a nuclear layer, most distinct towards the equator. The anterior surface of the lens is covered by a layer of transparent, nucleated columnar epithelium. At the equator the cells become elongated, and their gradual transition into lens-fibres can be traced (fig. 1028).

In the fœtus, the lens is nearly spherical and has a slightly reddish tint; it is soft and breaks down readily on the slightest pressure. A small branch (hyaloid artery) from the central artery of the retina runs forwards through the vitreous body to the posterior part of the capsule of the lens, where its branches radiate, forming a plexiform network which covers the posterior surface of the capsule, and is continuous round the margin of the capsule with the vessels of the pupillary membrane and with those of the iris. *In the adult*, the lens is colourless, transparent, firm in texture and devoid of vessels. *In old age*, it becomes flattened on both surfaces, slightly opaque, of an amber tint and increased in density (fig. 1027).

FIG. 1028.—A section through the margin of the lens, showing the transition of the columnar epithelium into the lens-fibres. (Babuchin.)



Vessels and Nerves.—The *arteries* of the eyeball are the long, short, and anterior ciliary arteries, and the central artery of the retina. They have already been described (pp. 1171 and 1176).

* Consult an article on "The Anatomy of the Living Eye as Revealed by the Gullstrand Slit-lamp," by Ida C. Mann (*Journal of Anatomy*, vol. lix. p. 155).

The *ciliary veins* are seen on the outer surface of the choroid, and are named, from their arrangement, the *venæ vorticosæ*; they converge to four or five equidistant trunks, which pierce the sclera midway between the sclerocorneal junction and the optic disc. Another set of veins accompanies the anterior ciliary arteries. All these veins open into the ophthalmic veins.

The *ciliary nerves* are derived from the nasociliary nerve and from the ciliary ganglion.

Applied Anatomy.—In the condition termed cataract the lens gradually becomes opaque and blindness ensues. In such cases sight may be restored by extraction of the lens and the provision of suitable glasses.

The Accessory Organs of the Eye

The accessory organs of the eye include the orbital muscles, the fasciæ, the eyebrows, the eyelids, the conjunctiva and the lacrimal apparatus.

The Orbital Muscles

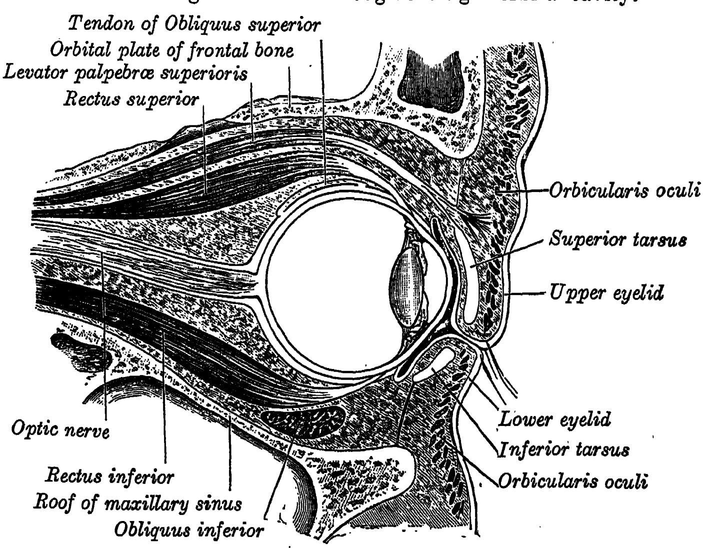
The orbital muscles are the:

Levator palpebræ superioris.	Rectus medialis.
Rectus superior.	Rectus lateralis.
Rectus inferior.	Obliquus superior.

Obliquus inferior.

The **Levator palpebræ superioris** (figs. 1029, 1030) is thin and triangular in shape. It arises from the under surface of the lesser wing of the sphenoid bone, above and in front of the optic foramen, from which it is separated by

Fig. 1029.—A sagittal section through the right orbital cavity.



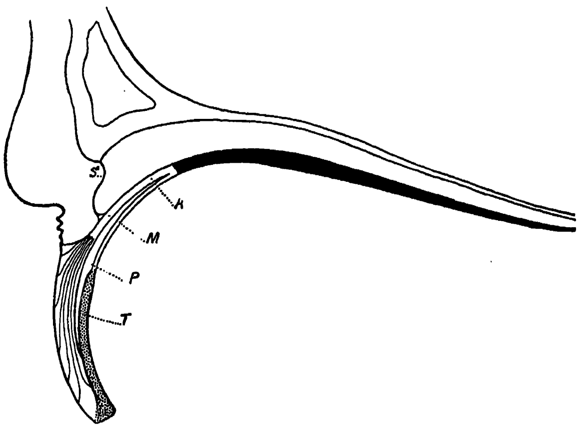
the origin of the Rectus superior. At its origin, it is narrow and tendinous but soon becomes broad and fleshy, the medial margin of the muscle being almost straight, while the lateral margin is concave. The muscle ends anteriorly in a wide aponeurosis which splits into two lamellæ. Some of the fibres of the superficial lamella are attached to the anterior surface of the superior tarsus (p. 1185), while others radiate and pass through the overlying Orbicularis oculi to the skin of the upper eyelid. The deep lamella consists of non-striped muscular fibres *; it is attached directly to the upper margin of the superior tarsus and is covered by conjunctiva on its inferior surface.

The fascial sheaths of the Levator palpebræ superioris and Rectus superior fuse. Where the two muscles separate to reach their insertions, the fascia between them forms a thick

* A layer of non-striped muscle is also present in the lower eyelid; it unites the inferior tarsus to the Obliquus inferior.

mass which is fixed to the superior conjunctival fornix and is described as an additional insertion of the Levator palpebræ superioris. When traced laterally the aponeurosis of the Levator palpebræ superioris passes between the lacrimal gland and its palpebral process, and is fixed to a tubercle on the zygomatic bone, just within the orbital margin (p. 326). When traced medially the aponeurosis loses its tendinous nature as it passes over and comes into close contact with the reflected tendon of the Obliquus superior, whence it can be

FIG. 1030.—A diagram of the Levator palpebræ superioris, showing its connexions. (From Whitnall's *Anatomy of the Human Orbit*, Oxford Medical Publications.)

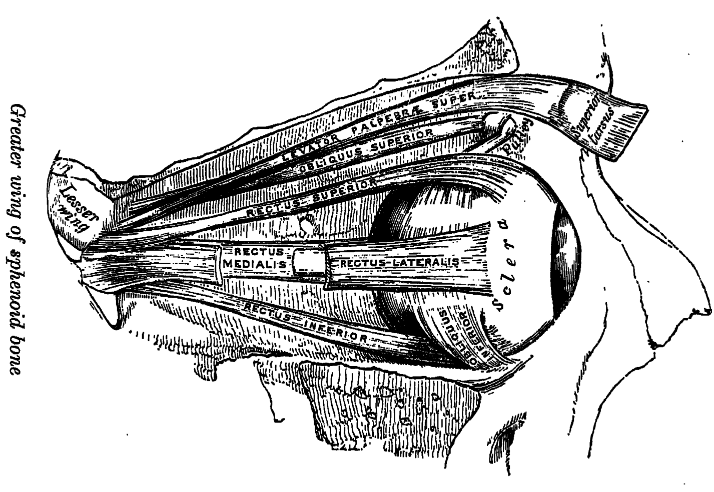


A, Superficial lamella of aponeurosis: *M*, Deep lamella (Müller's muscle); *P*, Interval between superficial and deep lamellæ of aponeurosis; *T*, Tarsus; *S*, Orbital septum.

followed with difficulty towards the medial palpebral ligament in the form of loose strands of connective tissue. When the Levator palpebræ contracts the upper eyelid is raised, but the lateral and medial parts of the aponeurosis are stretched and limit the action of the muscle; the elevation of the upper eyelid is checked also by the orbital septum.

The **four Recti** (figs. 1031, 1032) arise from a fibrous ring which surrounds the upper, medial, and lower margins of the optic foramen (fig. 1032), and is termed

FIG. 1031.—The muscles of the right orbit. Lateral aspect.

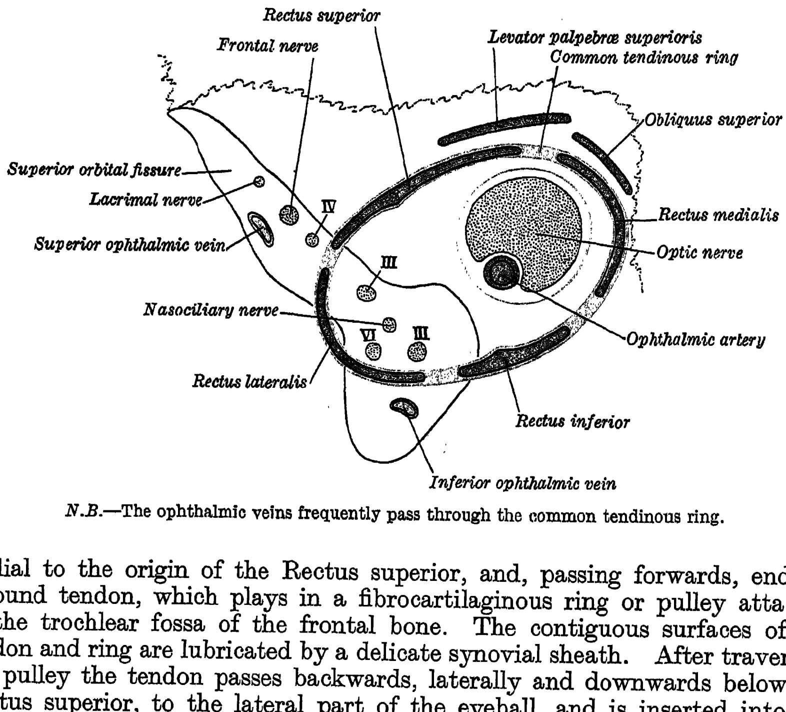


the *common tendinous ring* (annulus tendineus communis); the fibrous ring is continued across the lower and medial part of the superior orbital fissure and is attached to a tubercle on the margin of the greater wing of the sphenoid bone. The ring is closely adherent to the sheath of the optic nerve and to the surrounding periosteum; within it are (1) the optic foramen transmitting the optic nerve and ophthalmic artery, and (2) the medial part of the superior orbital

fissure which transmits the two divisions of the oculomotor nerve, the nasociliary nerve, and the abducent nerve. The superior ophthalmic vein may pass through, or above, the ring; the inferior ophthalmic vein through, or below, the ring. Two specialised parts of this fibrous ring may be made out: a lower, which gives origin to the Rectus inferior, a part of the Rectus medialis, and the lower fibres of the Rectus lateralis; and an upper, which gives origin to the Rectus superior, the other part of the Rectus medialis, and the upper fibres of the Rectus lateralis; a second small tendinous head of origin of the Rectus lateralis arises from the orbital surface of the greater wing of the sphenoid bone, lateral to the tendinous ring. Each muscle passes forward in the position implied by its name, to be inserted by a tendinous expansion into the sclera, about 6 mm. from the margin of the cornea.*

The **Obliquus superior** is a fusiform muscle, placed at the upper and medial side of the orbit. It arises above the optic foramen, superior and

FIG. 1032.—Scheme to show the common tendinous ring, the origins of the Recti, and the relative positions of the nerves entering the orbital cavity through the superior orbital fissure. (Modified from a figure in Whitnall's *Anatomy of the Human Orbit*, Oxford Medical Publications.)



N.B.—The ophthalmic veins frequently pass through the common tendinous ring.

medial to the origin of the Rectus superior, and, passing forwards, ends in a round tendon, which plays in a fibrocartilaginous ring or pulley attached to the trochlear fossa of the frontal bone. The contiguous surfaces of the tendon and ring are lubricated by a delicate synovial sheath. After traversing the pulley the tendon passes backwards, laterally and downwards below the Rectus superior, to the lateral part of the eyeball, and is inserted into the sclera, behind the equator of the eyeball, and between the Rectus superior and Rectus lateralis.

The **Obliquus inferior** is a thin, narrow muscle, placed near the anterior margin of the floor of the orbit. It arises from the orbital surface of the maxilla lateral to the nasolacrimal groove. Passing laterally, backwards and upwards, at first between the Rectus inferior and the floor of the orbit, and then between the eyeball and the Rectus lateralis, it is inserted into the lateral part of the sclera between the Rectus superior and Rectus lateralis, near to, but somewhat behind, the insertion of the Superior oblique muscle.

Nerves.—The Levator palpebræ superioris, the Obliquus inferior, and the Recti superior, inferior et medialis are supplied by the oculomotor nerve; the Obliquus superior, by the trochlear nerve; the Rectus lateralis, by the abducent nerve.

* The average distances of the insertions of the Recti from the margin of the cornea are: Rectus medialis, 5·5 mm.; Rectus inferior, 6·5 mm.; Rectus lateralis, 6·9 mm.; Rectus superior, 7·7 mm.

Actions.—The Levator palpebræ raises the upper eyelid, and is the direct antagonist of the Orbicularis oculi. The four Recti are attached to the eyeball in such a manner that, acting singly, they will turn its corneal surface either upwards, downwards, medially, or laterally, as expressed by their names. The movement produced by the Rectus superior and by the Rectus inferior is not quite a simple one, for inasmuch as each passes obliquely laterally and forwards to the eyeball, the elevation or depression of the cornea is accompanied by a certain deviation medially, with a slight amount of rotation. These latter movements are corrected by the oblique muscles. The obliquus inferior rotates the eyeball so as to turn its corneal surface upwards and laterally. When the eye is directed upwards, it corrects the medial deviation caused by the Rectus superior. The obliquus superior rotates the eyeball so as to turn its corneal surface downwards and laterally. When the eye is directed downwards, the superior oblique corrects the medial deviation caused by the Rectus inferior. The contraction of the Rectus lateralis or Rectus medialis, on the other hand, produces a purely horizontal movement. If any two neighbouring Recti of one eye act together they carry the globe of the eye in the diagonal of these directions, viz. upwards and medially, upwards and laterally, downwards and medially, or downwards and laterally. Sometimes the corresponding Recti of the two eyes act in unison, and at other times the opposite Recti act together. Thus, in turning the eyes to the right, the Rectus lateralis of the right eye acts in unison with the Rectus medialis of the left eye ; but if both eyes are directed to an object in the median plane at a short distance, the two medial Rectus muscles act in unison. The movement of circumduction, as in looking round a room, is performed by the successive actions of the four Recti. The Oblique muscles rotate the eyeball on its transverse and vertical axes, the superior directing the cornea downwards and laterally, and the inferior directing it upwards and laterally ; in addition, the oblique muscles rotate the globe of the eye round its anteroposterior axis ; these movements are required for the correct viewing of an object when the head is moved laterally, as from shoulder to shoulder, in order that the picture may fall in all respects on the same part of the retina of either eye.

A thin layer of non-striped muscle, named the *Orbitalis muscle*, bridges the inferior orbital fissure.

The **fascial sheath of the eyeball** (fascia bulbi) (figs. 1033, 1034) is a thin membrane which envelops the eyeball from the optic nerve to the sclerocorneal junction, separating it from the orbital fat and forming a socket in which it plays. Its inner surface is smooth, and is separated from the outer surface of the sclera by the *episcleral space* ; this space is traversed by delicate bands of connective tissue which extend between the fascia and the sclera. The fascia is perforated behind by the ciliary vessels and nerves, and fuses with the sheath of the optic nerve and with the sclera around the entrance of the optic nerve. In front it blends with the sclera just behind the sclerocorneal junction. It is perforated by the tendons of the orbital muscles, and is reflected on each as a tubular sheath. The sheath of the Superior oblique is carried as far as the fibrous pulley of that muscle ; that on the Inferior oblique reaches as far as the floor of the orbit, to which it gives off a slip. The sheaths on the Recti are gradually lost in the perimysium, but they give off important expansions. The expansion from the Rectus superior blends with the tendon of the Levator palpebræ superioris ; that of the Rectus inferior is attached to the inferior tarsus. The expansions from the sheaths of the Recti medialis et lateralis are strong and triangular in shape, and are attached to the lacrimal and zygomatic bones respectively ; as they probably check the actions of these two Recti they have been named the *medial* and *lateral check ligaments*. Lockwood * described a thickening of the lower part of the fascial sheath of the eyeball, which he named the *suspensory ligament of the eye* ; it is slung like a hammock below the eyeball, being expanded in the centre, and narrow at its extremities ; it is formed by the union of the margins of the sheath of the Rectus inferior with the medial and lateral check ligaments.

The **orbital fascia** forms the periosteum of the orbit, but is loosely connected to the bones. Behind, it is united with the dura mater and with the sheath of

* C. B. Lockwood, *Journal of Anatomy and Physiology*, vol. xx.

FIG. 1033.—A scheme of the fascia of the orbit (the muscle-sheaths and the fascial sheath of the eyeball) in sagittal section. (From Whitnall's *Anatomy of the Human Orbit*; Oxford Medical Publications.)

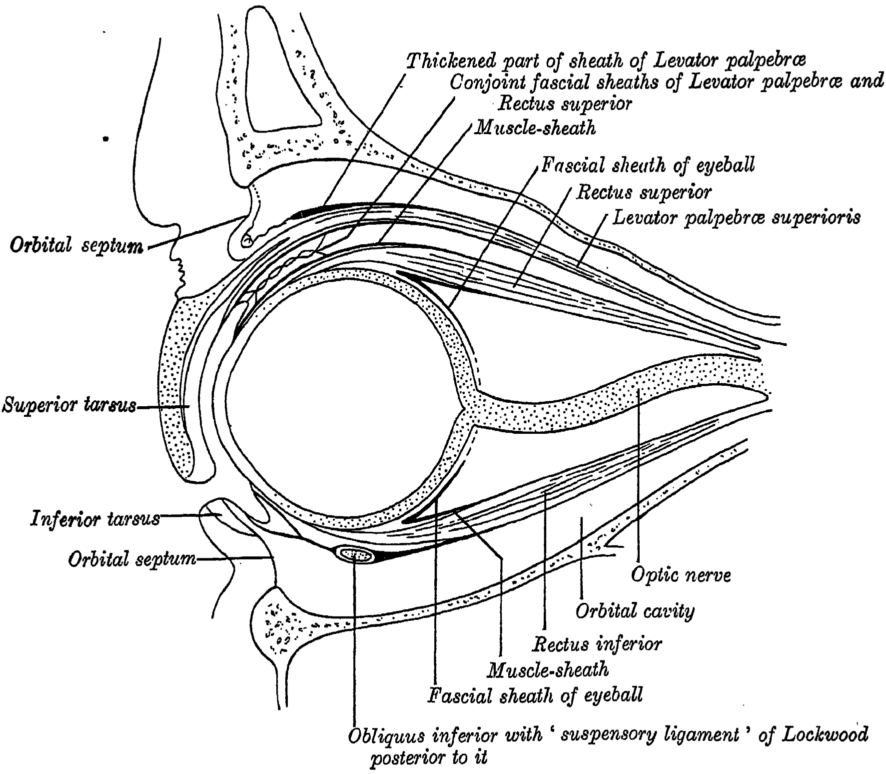
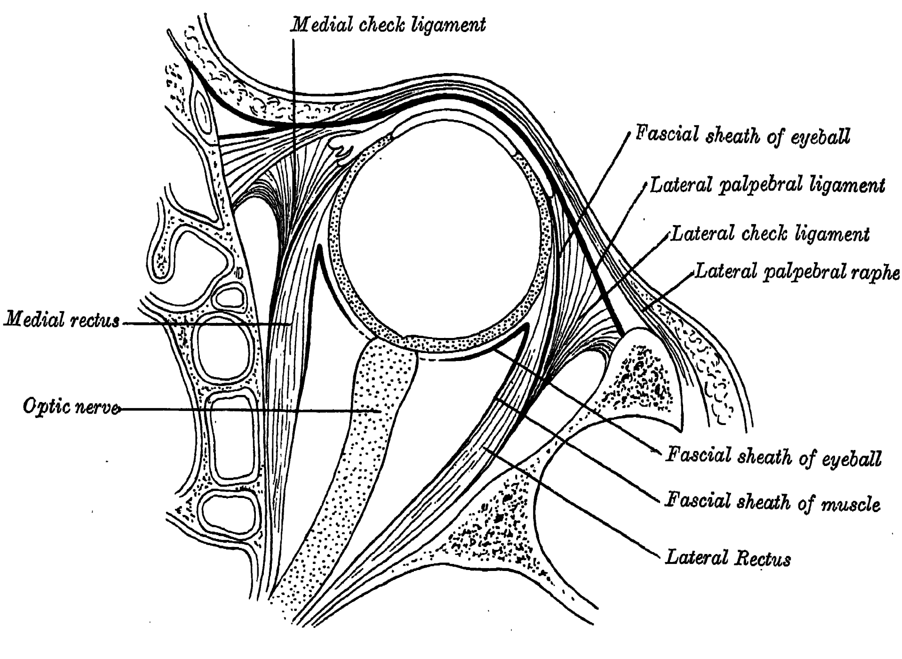


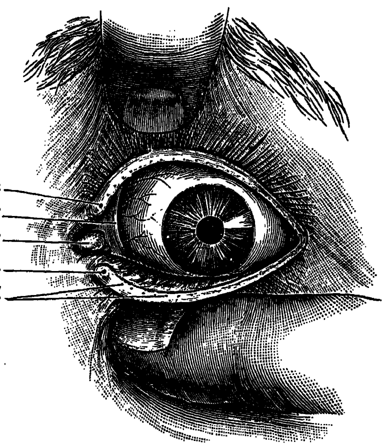
FIG. 1034.—A schematic view of a horizontal section through the right orbit to illustrate the fascia of the orbit. (From Whitnall's *Anatomy of the Human Orbit*; Oxford Medical Publications.)



the optic nerve. In front, it is connected with the periosteum at the margin of the orbit, and sends off a stratum which assists in forming the orbital septum. From it two processes are given off : one holds the pulley of the Superior oblique muscles in position, the other, named the *lacrimal fascia,* forms the roof and lateral wall of the sulcus in which the lacrimal sac is lodged (p. 1189).

Applied Anatomy.—The positions and exact areas of insertion of the tendons of the Recti medialis and lateralis into the globe of the eye should be carefully examined from the front, as the surgeon is often required to divide one or other of the muscles for the cure of strabismus. In convergent strabismus, which is the more common form of the disease, the eye is turned medially, and the condition may require the division of the Rectus medialis. In the divergent form, which is more rare, the eye is turned laterally, the Rectus lateralis being especially implicated. If the deformity produced in either case be marked, it may be remedied by division of one or the other muscle.

FIG. 1035.—The front of the left eye with the eyelids separated to show the plica semilunaris, caruncula lacrimalis and puncta lacrimalia.



The converse operation is that of *advancement,* in which either the Rectus medialis or Rectus lateralis (depending on the form of strabismus) is shortened. The muscle is exposed in a similar manner ; its tendon is divided, and sutured to the globe of the eye in front of its previous site of attachment.

Removal of the eyeball is effected by dividing the conjunctiva all round with scissors at its attachment to the cornea, after which each ocular muscle in turn is picked up on a blunt hook and divided close to the sclera. The optic nerve is then divided with curved scissors passed to the back of the orbit; it should be remembered that the perineural sheaths from the meninges are opened by this procedure.

The **eyebrows** are two arched eminences of skin, which surmount the orbits and support numerous short, thick hairs directed obliquely on the surface. Fibres of the Orbicularis oculi, Corrugator and frontal belly of the Occipitofrontalis are inserted into the skin of the eyebrows.

The **eyelids** or **palpebræ** are two thin, movable folds, placed in front of the eye, and protecting it, by their closure, from injury. The upper eyelid is the larger and more movable, and is furnished with an elevator muscle [the Levator palpebræ superioris] (p. 1179) ; the two eyelids unite with each other at their extremities. When the eyelids are open, an elliptical space, termed the *palpebral fissure* [*rima palpebrarum*], is left between their margins ; the extremities of the fissure are called the angles of the eye.

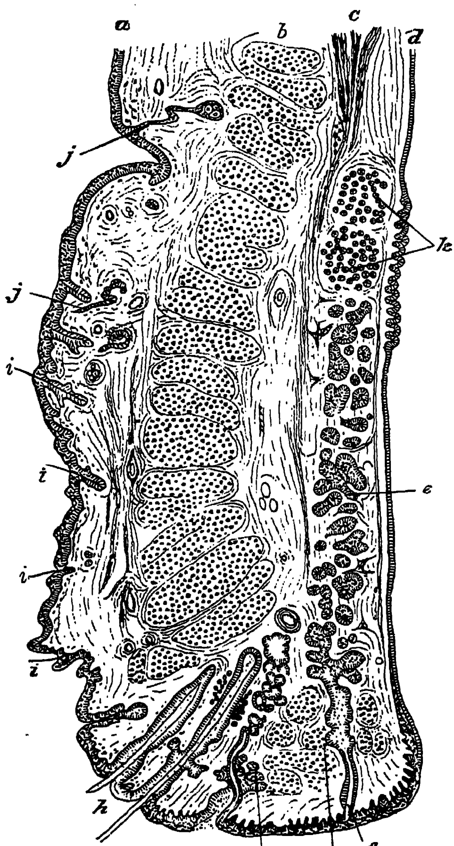
The *lateral angle of the eye* is more acute than the medial, and lies in close contact with the eyeball. The *medial angle* is prolonged for a short distance towards the nose, and is about 6 mm. away from the eyeball ; the two eyelids are here separated by a triangular space, named the *lacus lacrimalis,* in which a small reddish body, termed the *caruncula lacrimalis,* is situated (fig. 1035). On the margin of each eyelid, at the basal angles of the lacus lacrimalis, there is a small conical elevation, termed the *lacrimal papilla,* the apex of which is pierced by the commencement of the lacrimal canaliculus. This minute orifice (fig. 1035) is known as the *punctum lacrimale.*

The *eyelashes* are attached to the free edges of the eyelids from the lateral angle of the eye to the lacrimal papillæ. They are short, thick, curved hairs, arranged in double or triple rows : those of the upper eyelid, more numerous and longer than those of the lower, curve upwards ; those of the lower eyelid curve downwards so that the upper and lower eyelashes do not interlace when

the lids are closed. A number of enlarged and modified sudoriferous glands, termed *ciliary glands*, are arranged in several rows close to the free margin of each lid and open near the attachments of the eyelashes.

Structure of the eyelids.—From without inwards, each eyelid consists of: skin, subcutaneous areolar tissue, fibres of the Orbicularis oculi, tarsus and orbital septum, tarsal glands and conjunctiva. The upper eyelid has, in addition, the aponeurosis of the Levator palpebræ superioris (fig. 1036).

FIG. 1036.—A sagittal section through the upper eyelid. (After Waldeyer.)



a. Skin. b. Orbicularis oculi. b'. Ciliary bundle of the Orbicularis oculi. c. Levator palpebræ superioris. d. Conjunctiva. e. Tarsal glands embedded in the tarsal plate. f. Opening of a tarsal gland. g. Sebaceous gland. h. Eyelashes. i. Small hairs of the skin. j. Sweat gland. k. Posterior tarsal glands.

The *skin* is extremely thin, and continuous at the margins of the eyelids with the conjunctiva.

The *subcutaneous areolar tissue* is very lax and delicate, and seldom contains any fat.

The *palpebral fibres of the Orbicularis oculi* are thin, pale in colour and parallel with the palpebral fissure.

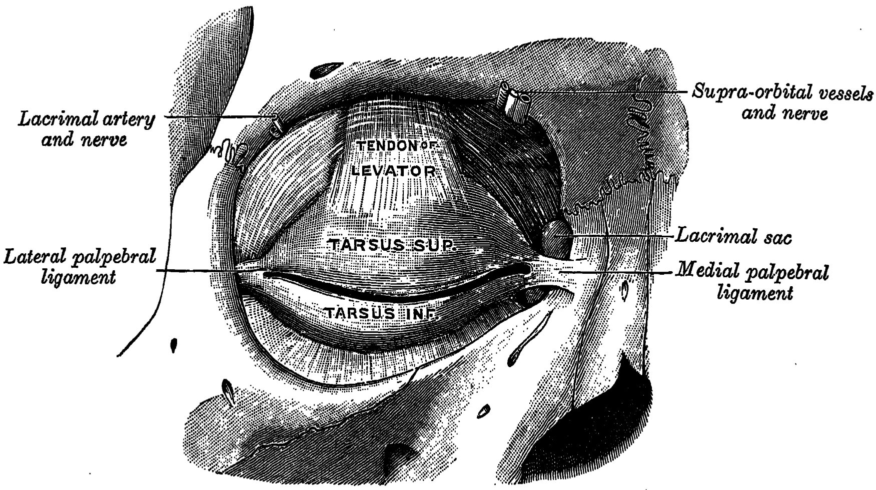
The *tarsi* (fig. 1037) are two thin elongated plates of dense connective tissue, about 2·5 cm. long; one is placed in each eyelid and contributes to its form and support. The *tarsus of the upper eyelid*, the larger, is of a semioval form, about 10 mm. in height at the centre, and gradually narrowing towards its extremities. The lowest fibres of the superficial lamella of the aponeurosis of the Levator palpebræ superioris are attached to its anterior surface, and the deep lamella of the same aponeurosis is inserted into its upper margin (p. 1179). The *tarsus of the lower eyelid*, the smaller, is a narrow plate, the vertical diameter of which is about 5 mm. The free or ciliary margins of the tarsi are thick and straight. The attached or orbital margins are connected to the circumference of the orbit by the orbital septum. The lateral ends of the tarsi are attached by a band, named the *lateral palpebral ligament*, to a tubercle on the zygomatic bone, just within the orbital margin; this ligament is separated from the more superficially placed lateral palpebral raphe (p. 527) by a few lobules of the lacrimal gland. The medial ends of the tarsi are attached by a strong tendinous band, named the *medial palpebral ligament*; to the upper part of the lacrimal crest, and to the adjoining part of the frontal process of the maxilla in front of this crest; the lower edge of this ligament is separated from the lacrimal sac by some fibres of the Orbicularis oculi.

The *orbital septum* is a weak membranous sheet, attached to the edge of the orbit, where it is continuous with the periosteum. In the upper eyelid it blends with the superficial lamella of the aponeurosis of the Levator palpebræ superioris, and in the lower eyelid with the anterior surface of the tarsus. It is perforated by the vessels and nerves which pass from the orbital cavity to the face and scalp, by the aponeurosis of the Levator palpebræ superioris, and by the palpebral process of the lacrimal gland.

The *tarsal glands* (fig. 1038) are situated between the tarsi and the conjunctiva, and may be distinctly seen through the latter on everting the eyelids; they present an appearance like parallel strings of pearls. There are about thirty in the upper eyelid, and somewhat fewer in the lower. They are im-

bedded in grooves on the deep surfaces of the tarsi and correspond in length with the breadth of these plates; they are, consequently, longer in the upper

FIG. 1037.—The tarsi and their ligaments. Anterior aspect. (Testut.)



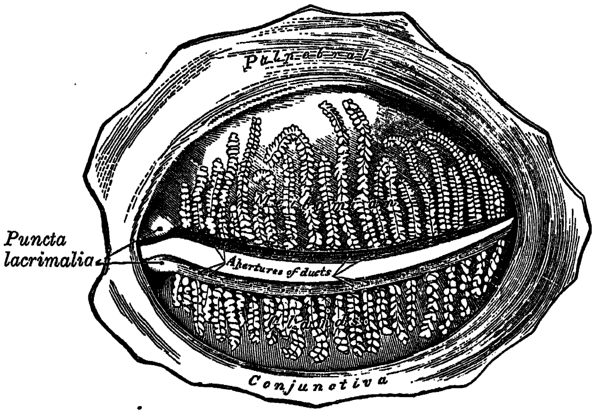
than in the lower eyelid. Their ducts open on the free margins of the lids by minute foramina.

Structure.—The tarsal glands are modified sebaceous glands, each consisting of a straight tube or follicle, with numerous small lateral diverticula. The tubes are supported by a basement-membrane and are lined at their mouths by stratified epithelium; the deeper parts of the tubes and the lateral offshoots are lined by a layer of polyhedral cells.

The **conjunctiva** is the mucous membrane which lines the inner surfaces of the eyelids, and is reflected over the fore part of the sclera and the cornea.

The *palpebral portion* is thick, opaque and highly vascular, and has numerous subepithelial connective tissue papillæ, its deeper part containing a considerable amount of lymphoid tissue. At the margins of the lids it is continuous with the skin, with the lining epithelium of the ducts of the tarsal glands, and, through the lacrimal canaliculi, with the lining membrane of the lacrimal sac and nasolacrimal duct. The line of reflection of the conjunctiva from the eyelids on to the eyeball is named the *conjunctival fornix*, and its different parts are known as the superior and inferior fornices; the ducts of the lacrimal gland open into the lateral part of the superior fornix. Upon the *sclera* the conjunctiva is loosely connected to the eyeball; it is thin, transparent, destitute of papillæ, and only slightly vascular. Upon the *cornea*, the conjunctiva consists only of epithelium, constituting the epithelium of the cornea, already described (p. 1166). The epithelium of the palpebral conjunctiva is columnar, that of the

FIG. 1038.—The tarsal glands of the eyelids. Posterior aspect.



ocular conjunctiva and the cornea is stratified squamous. Glands, analogous to lymphoid follicles, and called by Henle *trachoma glands*, are found in the conjunctiva, chiefly near the medial angle of the eye.

The *lacrimal caruncle* (fig. 1035) is a small, reddish, conical body situated in the lacus lacrimalis at the medial angle of the eye; it consists of a small island of skin, and contains sebaceous and sudoriferous glands; a few slender hairs are attached to its surface. Lateral to the caruncula there is a semilunar fold of conjunctiva [the *plica semilunaris*], the concavity of which is directed towards the cornea.

Vessels and Nerves.—The eyelids receive their blood-supply from the medial palpebral branches of the ophthalmic artery and from the lateral palpebral branches of the lacrimal artery (p. 722).

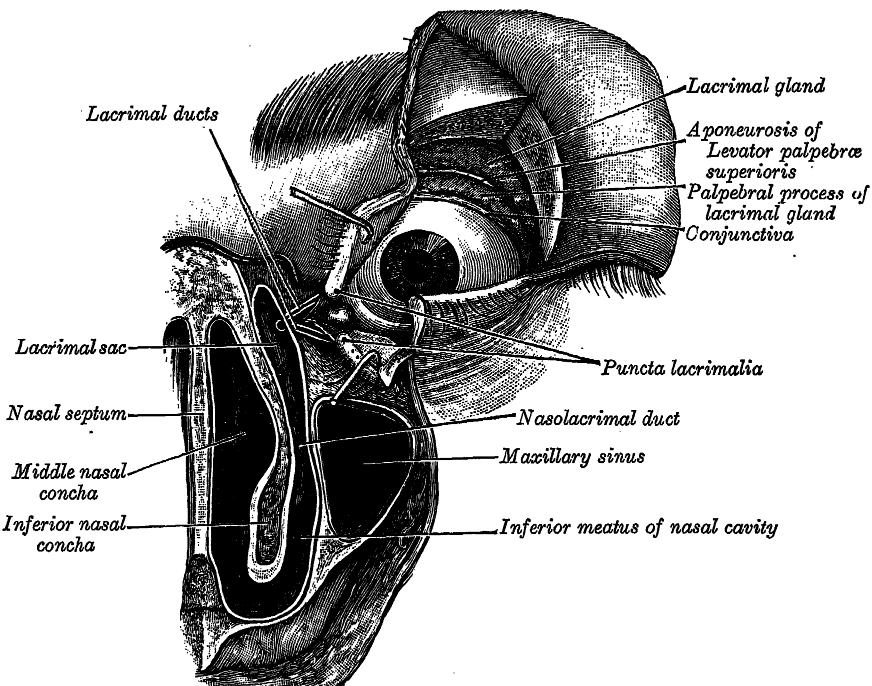
The upper half of the conjunctiva is supplied by the ophthalmic division of the trigeminal nerve, and the lower half by the maxillary division. Many of the nerves to the conjunctiva end in bulbous corpuscles (p. 1216).

The lymph vessels of the eyelids and the conjunctiva are described on p. 853.

The Lacrimal Apparatus (figs. 1039 to 1041)

The lacrimal apparatus consists of (*a*) the lacrimal gland, which secretes the tears, and its excretory ducts which convey the fluid to the surface of the eye; (*b*) the lacrimal canaliculi, the lacrimal sac, and the nasolacrimal duct, by which the fluid is conveyed into the cavity of the nose.

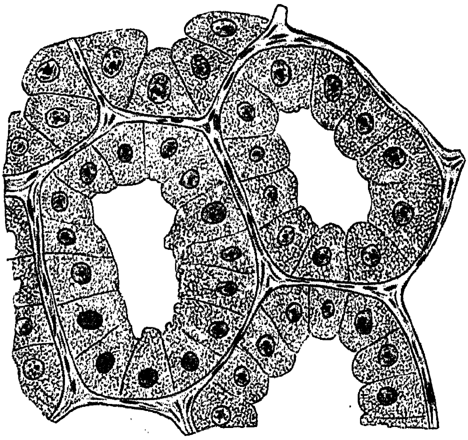
Fig. 1039.—The left lacrimal apparatus. Exposed from the front.



The lacrimal gland (fig. 1039) is lodged in the lacrimal fossa, on the medial side of the zygomatic process of the frontal bone. It is about the size and shape of an almond, and its inferolateral aspect sends a *palpebral process* into the lateral part of the upper eyelid. The gland and its process are continuous with each other around the lateral edge of the aponeurosis of the Levator palpebræ superioris. The *lacrimal gland* is connected to the periosteum of the orbit by a few fibrous bands; its *palpebral process* lies below the aponeurosis of the

Levator palpebræ superioris, and projects into the posterior part of the upper eyelid, where it lies upon and is adherent to the conjunctiva. The ducts of the glands, from six to twelve in number, run obliquely beneath the conjunctiva for a short distance, and open along the lateral part of the superior conjunctival fornix.

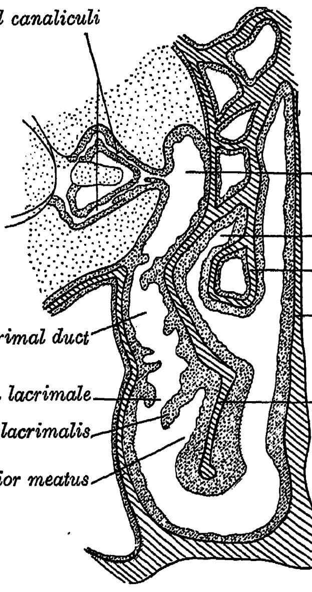
Fig. 1040.—A transverse section through a portion of the lacrimal gland of a cat. ×250.



Many, small, accessory lacrimal glands are present in and near the conjunctival fornices; they are more numerous in the upper lid than in the lower. Their existence may explain why the conjunctiva does not dry up after extirpation of the lacrimal gland proper.

Structure of the lacrimal gland (fig. 1040).—In structure the lacrimal resembles the salivary glands (p. 1270), but there are no crescents of Gianuzzi. It is a compound racemose gland, the alveoli of which are lined with columnar cells resting on a basement-membrane. The cells contain oval nuclei, and in the resting condition are crowded with small, clear vacuoles, which disappear when the gland secretes actively; protoplasmic granules are also present. The excretory ducts are lined with columnar epithelial cells, but these cells do not show the rod-like structures of the corresponding cells in the salivary glands.

Fig. 1041.—Sketch from a coronal section through the right half of the nasal cavity, viewed from the front, to show the relation of the lacrimal passages to the maxillary and ethmoidal sinuses and the inferior nasal concha. The mucous membrane is coloured. (After Gerard, 1907; from Whitnall's *Anatomy of the Human Orbit*; Oxford Medical Publications.)



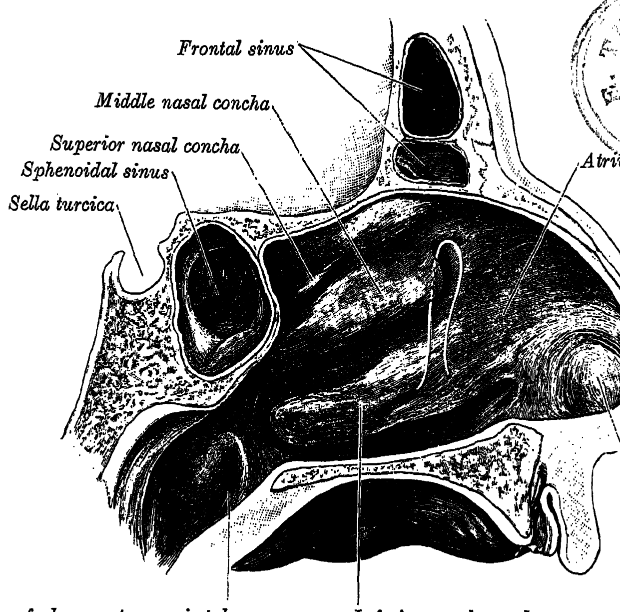
The **lacrimal canaliculi** (lacrimal ducts), one in each eyelid, are about 10 mm. long; they commence at the *puncta lacrimalia* (figs. 1035, 1039, 1041). The *superior canaliculus*, smaller and shorter than the inferior, at first ascends, and then bends at an acute angle, and passes medially and downwards to the lacrimal sac. The *inferior canaliculus* at first descends, and then runs almost horizontally to the lacrimal sac. At the angles they are dilated into *ampullæ*. The mucous lining of the ducts is covered with stratified squamous epithelium, placed on a basement-membrane, and outside the latter there is a layer of striped muscular fibres, continuous with the lacrimal part of the Orbiculari oculi; at the base of each lacrimal papilla the muscular fibres are circularly arranged and form a kind of sphincter.

The **lacrimal sac** (fig. 1041) is the upper end of the nasolacrimal duct, and is lodged in a fossa formed by the lacrimal bone, the frontal process of the maxilla and the lacrimal fascia. It measures about 12 mm. in length; its upper, closed end is flattened from side to side, but its lower part is rounded,

and is continued into the nasolacrimal duct; the openings of the lacrimal canaliculi are situated in its lateral wall.

Relations.—A layer of fascia, continuous with the periosteum of the orbit and named the *lacrimal fascia*, passes from the lacrimal crest of the maxilla to the crest of the lacrimal bone, and forms the roof and lateral wall of the fossa in which the lacrimal sac is lodged; between the fascia and the lacrimal sac there is a minute plexus of veins. The lacrimal fascia separates the sac from the medial palpebral ligament in front, and from the lacrimal part of the

FIG. 1042.—A sagittal section through the anterior part of the head of an adult female. Left half viewed from within to show the left lateral nasal wall. The relative positions of the fossa for the lacrimal sac and the nasolacrimal duct are indicated by the white line. × about ⅜. (From Whitnall's *Anatomy of the Human Orbit*; Oxford Medical Publications.)



Orbicularis oculi behind. The lower half of the fossa which lodges the lacrimal sac is related medially to the anterior part of the middle meatus of the nasal cavity; the upper half is related to the anterior ethmoidal sinuses.*

Structure.—The lacrimal sac consists of a fibro-elastic coat, lined internally by mucous membrane; the latter is continuous, through the lacrimal canaliculi, with the conjunctiva, and through the nasolacrimal duct with the mucous membrane of the nasal cavity.

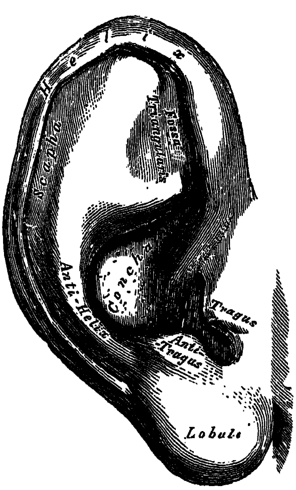
The tears pass from the superolateral to the inferomedial angle of the conjunctival sac, where they enter the puncta lacrimalia. They then traverse the lacrimal canaliculi and so reach the lacrimal sac. Their passage across the eyeball is effected by the movements of the eyelids and by capillarity.

The **nasolacrimal duct** (figs. 1041, 1042) is a membranous canal about 18 mm. long, which extends from the lower part of the lacrimal sac to the anterior part of the inferior meatus of the nose, where it ends in a somewhat expanded orifice. A fold of the mucous membrane forms an imperfect valve just above the opening and is known as the *lacrimal fold* [plica lacrimalis]. The duct is contained in an osseous canal, formed by the maxilla, the lacrimal bone and the inferior nasal concha; it is narrower in the middle than at either

* S. E. Whitnall (*Ophthalmic Review*, Nov. 1911) examined 100 skulls and found that in 14 the anterior ethmoidal air-sinuses came into relation only with the posterior wall of the fossa; in 32 they reached as far forward as the suture between the lacrimal bone and the maxilla; while in 54 one large irregular air-sinus extended forward as far as the anterior lacrimal crest.

end, and is directed downwards, backwards and a little laterally. The mucous lining of the lacrimal sac and nasolacrimal duct is covered with columnar epithelium which in places is ciliated.

FIG. 1043.—The right auricle. Lateral surface.



THE ORGAN OF HEARING

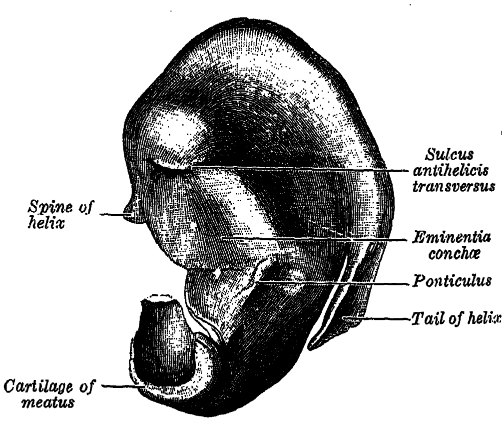
The ear or organ of hearing is divisible into three parts: the external ear, the middle ear or tympanic cavity, and the internal ear or labyrinth.

THE EXTERNAL EAR

The **external ear** consists of the expanded portion named the *auricle* and the *external auditory meatus.* The former projects from the side of the head and serves to collect the air-vibrations by which sound is produced; the latter leads inwards from the bottom of the auricle and conducts the vibrations to the tympanic cavity.

The **auricle** (fig. 1043) is of an oval form, with its larger end directed upwards. Its lateral surface is irregularly concave, looks slightly forwards, and presents numerous eminences and depressions. The prominent rim of the auricle is called the *helix*; where the helix turns downwards posteriorly, a small tubercle termed the *auricular tubercle,* is frequently seen; this tubercle is very evident about the sixth month of fœtal life, when the whole auricle has a close resemblance to that of some of the adult monkeys. Another curved prominence, parallel with and in front of the posterior part of the helix, is called the *antihelix*; this divides above into two crura, between which is a triangular depression, named the *triangular fossa.* The narrow curved depression between the helix and the antihelix is called the *scaphoid fossa*; the antihelix partly encircles a deep, capacious cavity, named the *concha of the auricle,* which is incompletely divided into two parts by the *crus* or anterior end of the helix. Below the crus of the helix and in front of the concha, a small, curved flap, termed the *tragus,* projects backwards over the orifice of the meatus. Opposite the tragus, and separated from it by the *intertragic notch,* there is a small tubercle, named the *antitragus.* The *lobule,* composed of fibrous and adipose tissues, and devoid of the firmness and elasticity of the rest of the auricle, lies below the antitragus.

FIG. 1044.—The cranial surface of the cartilage of the right auricle.



The cranial surface of the auricle presents elevations which correspond to the depressions on its lateral surface, and after which they are named, e.g. eminentia conchæ, eminentia triangularis, etc.

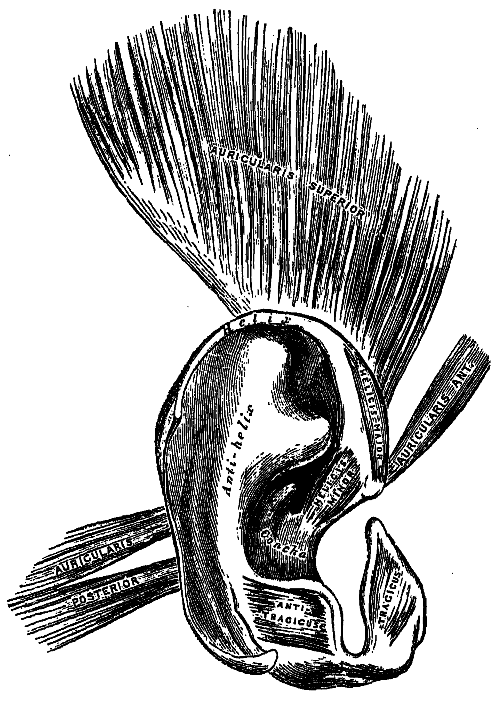
Structure.—The auricle is composed of a thin plate of elastic fibrocartilage, covered with skin, and connected with the surrounding parts by ligaments and muscles; it is continuous with the cartilaginous portion of the external auditory meatus, and the latter is joined to the margins of the bony meatus by fibrous tissue.

The *skin of the auricle* is thin, closely adherent to the cartilage, and covered with fine

hairs which are furnished with sebaceous glands; these glands are most numerous in the concha and scaphoid fossa. On the tragus and antitragus, and in the intertragic notch the hairs are strong and numerous. The skin of the auricle is continuous with that lining the external auditory meatus.

The *cartilage of the auricle* (figs. 1044, 1045) consists of a single piece; upon its surface the eminences and depressions above described are found. It is absent from the lobule; it is deficient, also, between the tragus and beginning of the helix, the gap being filled up by dense fibrous tissue. At the front part of the auricle, where the helix bends upwards, there is a small projection of the cartilage, called the *spine of the helix*, while in the lower part of the helix the cartilage is prolonged downwards as a tail-like process, named the *tail of the helix*; the latter is separated from the antihelix by the *fissura antitragohelicina*. The cranial surface of the cartilage exhibits a transverse furrow, named the *sulcus antihelicis transversus*, which corresponds with the inferior crus of the antihelix and separates the eminentia conchæ from the eminentia triangularis. The eminentia conchæ is crossed by a vertical ridge (*ponticulus*) which gives attachment to the Auricularis posterior muscle. In the cartilage of the auricle there are two fissures, one behind the crus helicis and another in the tragus.

FIG. 1045.—The muscles of the right auricle.



The *ligaments of the auricle* consist of two sets: (1) extrinsic, connecting it to the temporal bone; (2) intrinsic, connecting various parts of its cartilage together.

The *extrinsic ligaments* are two in number, anterior and posterior. The *anterior ligament* extends from the tragus and spine of the helix to the root of the zygomatic process of the temporal bone. The *posterior ligament* passes from the posterior surface of the concha to the lateral surface of the mastoid process.

The chief *intrinsic ligaments* are: (*a*) a strong fibrous band, stretching from the tragus to the helix, completing the meatus in front, and partly encircling the boundary of the concha; and (*b*) a band between the antihelix and the tail of the helix. Other less important bands are found on the cranial surface of the auricle.

The *muscles of the auricle* (fig. 1045) consist of two sets: (1) the extrinsic, which connect it with the skull and scalp and move the auricle as a whole; and (2) the intrinsic, which extend from one part of the auricle to another.

The extrinsic muscles are the Auriculares anterior, superior et posterior.

The *Auricularis anterior*, the smallest of the three, is thin, fan-shaped, and its fibres are pale and indistinct. It arises from the lateral edge of the epicranial aponeurosis, and its fibres converge to be inserted into the spine of the helix.

The *Auricularis superior*, the largest of the three, is thin and fan-shaped. Its fibres arise from the epicranial aponeurosis, and converge to be inserted by a thin, flattened tendon into the upper part of the cranial surface of the auricle.

The *Auricularis posterior* consists of two or three fleshy fasciculi, which arise by short aponeurotic fibres from the mastoid portion of the temporal bone, and are inserted into the ponticulus on the eminentia conchæ.

Nerve-supply.—The Auriculares anterior et superior are supplied by the temporal branches, and the Auricularis posterior by the posterior auricular branch, of the facial nerve.

Actions.—In man, these muscles possess very little action; the Auricularis anterior draws the auricle forwards and upwards; the Auricularis superior raises it slightly; and the Auricularis posterior draws it backwards.

The intrinsic muscles are the:

Helicis major.	Antitragicus.
Helicis minor.	Transversus auriculæ.
Tragicus.	Obliquus auriculæ.

The *Helicis major* is a narrow vertical band situated upon the anterior margin of the helix. It arises from the spine of the helix, and is inserted into the anterior border of the helix, where the latter is about to curve backwards.

The *Helicis minor* is an oblique fasciculus, covering the crus helicis.

The *Tragicus* is a short, flattened vertical band on the lateral surface of the tragus.

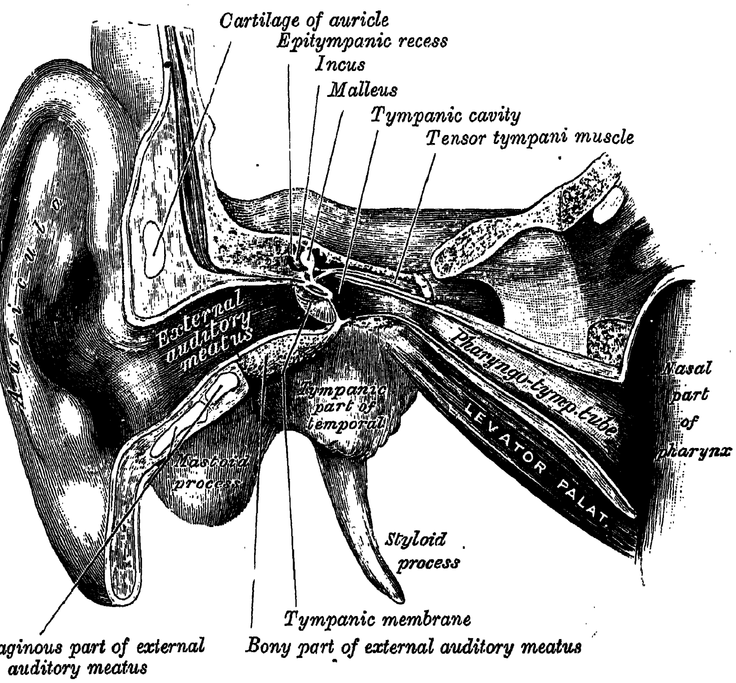
The *Antitragicus* arises from the outer part of the antitragus, and is inserted into the tail of the helix and antihelix.

The *Transversus auriculæ* is placed on the cranial surface of the auricle. It consists of scattered fibres, partly tendinous and partly muscular, extending from the eminentia conchæ to the eminentia scaphæ.

The *Obliquus auriculæ*, also on the cranial surface, consists of a few fibres extending from the upper and posterior parts of the eminentia conchæ to the eminentia triangularis.

Nerve-supply.—The intrinsic muscles on the lateral surface are supplied by the temporal branches of the facial nerve, the intrinsic muscles on the cranial surface by the posterior auricular branch of the same nerve.

FIG. 1046.—The external and middle portions of the right ear, from the front.



The *arteries of the auricle* are: (*a*) the posterior auricular branch of the external carotid artery, which supplies three or four branches to the cranial surface; twigs from these reach the lateral surface, some by passing through the fissures of the auricular cartilage, and others by turning round the margin of the helix; (*b*) the anterior auricular branches of the superficial temporal artery, which are distributed to the lateral surface; and (*c*) a branch from the occipital artery.

The *veins* accompany the corresponding arteries.

The *sensory nerves* are: the great auricular and lesser occipital nerves, from the cervical plexus; the auriculotemporal branch of the mandibular nerve; and the auricular branch of the vagus nerve.

The **external auditory meatus** extends from the bottom of the concha to the tympanic membrane (figs. 1046, 1047). It is about 4 cm. long if measured from the tragus; from the bottom of the concha its length is about 2·5 cm. It forms an S-shaped curve, and is directed at first medially, forwards, and slightly upwards (*pars externa*); it then passes medially, backwards, and upwards (*pars media*), and lastly is carried medially, forwards, and slightly downwards (*pars interna*). It is an oval cylindrical canal, the greatest diameter of the oval being directed downwards and backwards at the external orifice, but nearly hori-

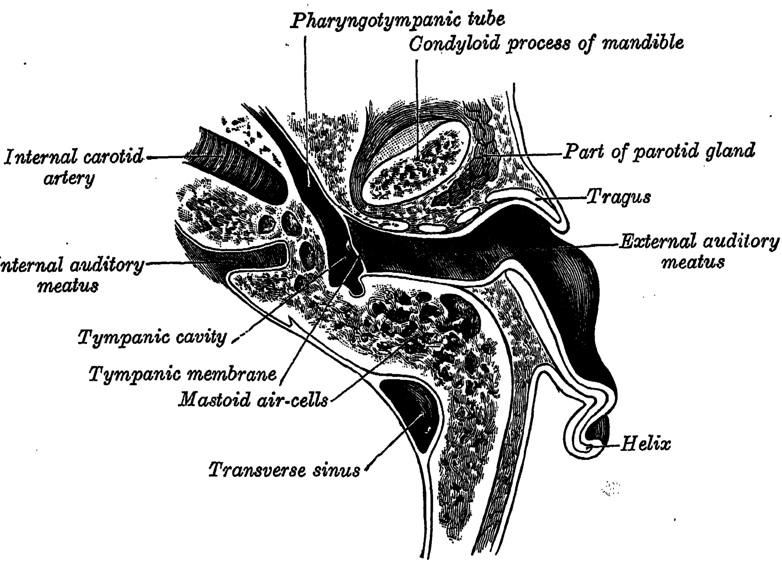
zontally at the medial end. It presents two constrictions, one near the medial end of the cartilaginous portion, and another, named the *isthmus*, in the osseous portion, about 2 cm. from the bottom of the concha. The tympanic membrane, which closes the medial end of the meatus, is obliquely directed; in consequence of this obliquity the floor and anterior wall of the meatus are longer than the roof and posterior wall.

The external auditory meatus is formed partly by cartilage and membrane, and partly by bone, and is lined by skin.

The *cartilaginous portion* is about 8 mm. long; it is continuous with the cartilage of the auricle and is fixed to the circumference of the osseous portion. The cartilage is deficient at the upper and posterior parts of the meatus, its place being supplied by fibrous membrane; two or three deep fissures are present in the anterior part of the cartilage.

The *osseous portion* is about 16 mm. long, and is narrower than the cartilaginous portion. It is directed medially, forwards, and slightly downwards,

FIG. 1047.—A horizontal section through the left ear. Upper half of the section.



forming in its course a slight curve the convexity of which is upwards and backwards. Its medial end is smaller than the lateral end, and is sloped, the anterior wall projecting beyond the posterior for about 4 mm.; this end is marked, except at its upper part, by a narrow groove, named the *tympanic sulcus*, in which the circumference of the tympanic membrane is attached. Its lateral end is dilated, and rough in the greater part of its circumference for the attachment of the cartilaginous portion. The anterior and inferior parts of the osseous portion are formed by the tympanic part of the temporal bone, which, in the fœtus, exists as the tympanic ring (p. 301).

The skin which envelops the auricle is continued into the external auditory meatus and covers the outer surface of the tympanic membrane. It is thin and closely adherent to the cartilaginous and osseous parts of the tube. After maceration, the thin pouch of epidermis, when withdrawn, preserves the form of the meatus. In the thick subcutaneous tissue of the cartilaginous part of the meatus there are numerous *ceruminous glands*, which secrete the ear-wax; their structure resembles that of the sudoriferous glands (p. 1225).

Relations of the meatus.—The condyloid process of the mandible lies in front of the meatus, but the two are sometimes separated by a small portion of the parotid gland. The movements of the mandible influence to some extent the lumen of the cartilaginous portion. Above the osseous part is the middle cranial fossa; behind it are the mastoid air-cells, separated from the meatus by a thin layer of bone.

The *arteries* supplying the meatus are branches from the posterior auricular, (internal) maxillary, and temporal arteries.

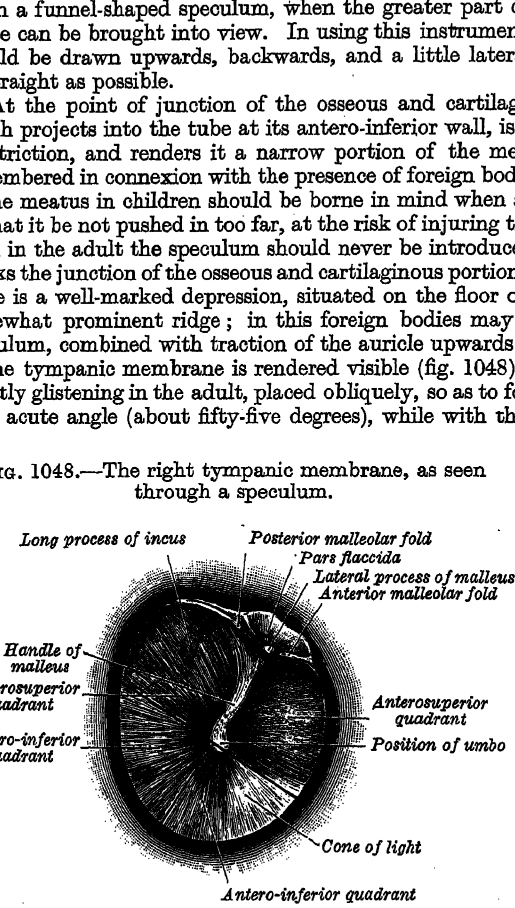
The *nerves* are chiefly derived from the auriculotemporal branch of the mandibular nerve and the auricular branch of the vagus nerve.

Applied Anatomy.—Malformations, such as imperfect development of the external parts, supernumerary auricle, or absence of the meatus, are occasionally met with.

The external auditory meatus can be examined most satisfactorily by light reflected down a funnel-shaped speculum, when the greater part of the canal and tympanic membrane can be brought into view. In using this instrument, it is advisable that the auricle should be drawn upwards, backwards, and a little laterally, so as to render the meatus as straight as possible.

At the point of junction of the osseous and cartilaginous portions an obtuse angle, which projects into the tube at its antero-inferior wall, is formed; this produces a sort of constriction, and renders it a narrow portion of the meatus—an important point to be remembered in connexion with the presence of foreign bodies in the meatus. The shortness of the meatus in children should be borne in mind when an aural speculum is introduced, so that it be not pushed in too far, at the risk of injuring the tympanic membrane; indeed even in the adult the speculum should never be introduced beyond the constriction which marks the junction of the osseous and cartilaginous portions. Just in front of the membrane there is a well-marked depression, situated on the floor of the meatus, and bounded by a somewhat prominent ridge; in this foreign bodies may become lodged. By aid of the speculum, combined with traction of the auricle upwards and backwards, the greater part of the tympanic membrane is rendered visible (fig. 1048). It is a pearly-grey membrane, slightly glistening in the adult, placed obliquely, so as to form with the floor of the meatus a very acute angle (about fifty-five degrees), while with the roof it forms an obtuse angle. At birth it is more horizontal, situated in almost the same plane as the base of the skull. A reddish-yellow streak can be seen about midway between the anterior and posterior margins of the membrane, and extending from the centre obliquely upwards and forwards; this is the handle of the malleus, which is attached to the membrane. At the upper part of this streak, close to the roof of the meatus, a little white, round prominence is plainly to be seen; this is the lateral or short process of the malleus, projecting against the membrane. The tympanic membrane does not present a plane surface; on the contrary, its centre is drawn inwards, on account of its connexion with the manubrium of the malleus.

Fig. 1048.—The right tympanic membrane, as seen through a speculum.



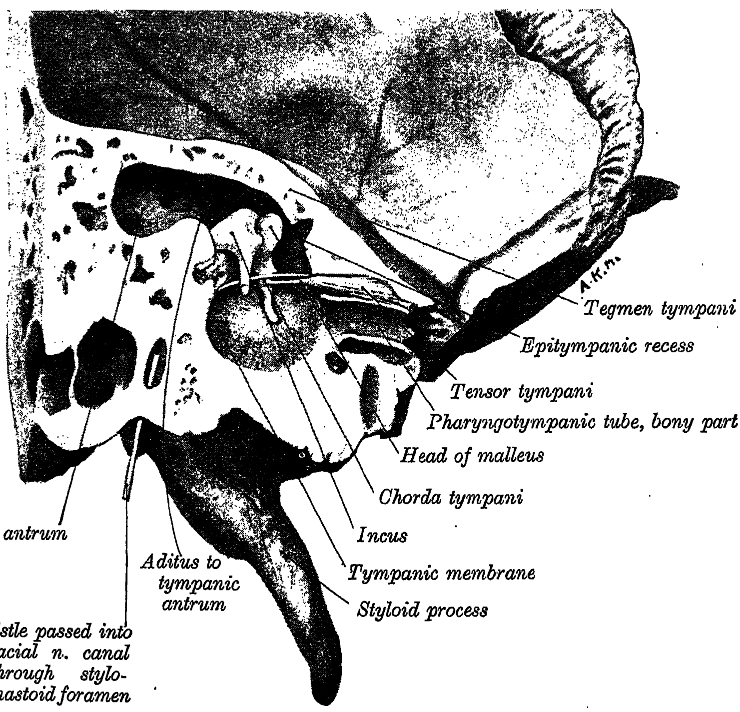
The connexions of the nerves of the meatus explain the occurrence of constant coughing and sneezing, from implication of the vagus, when there exists any source of irritation in the meatus; and the vomiting which may follow syringing the ears of children, and the occasional heart failure similarly induced in elderly people. No doubt also the association of earache with toothache or with cancer of the tongue is due to implication of the mandibular branch of the trigeminal nerve, which supplies the teeth and the tongue also. The upper half of the tympanic membrane is much more vascular than the lower half; for this reason, and also to avoid the chorda tympani nerve and ossicles, incisions through the membrane should be made at the lower and posterior part.

The Middle Ear, or Tympanic Cavity

The middle ear or tympanic cavity, is an irregular, laterally compressed space within the temporal bone. It is lined with mucous membrane (p. 1202) and filled with air, which is conveyed to it from the nasal part of the pharynx through the pharyngotympanic tube (auditory tube). It contains a chain of movable bones, which connect its lateral to its medial wall and transmit the vibrations of the tympanic membrane across the cavity to the internal ear.

The tympanic cavity consists of two parts: the *tympanic cavity proper*, opposite the tympanic membrane, and the *epitympanic recess*, above the level of the membrane; the latter contains the upper half of the malleus and the greater part of the incus. Including the epitympanic recess, the vertical and anteroposterior diameters of the cavity are each about 15 mm. The transverse diameter measures about 6 mm. above and 4 mm. below; opposite the centre of the tympanic membrane it is only about 2 mm. The tympanic cavity is bounded laterally by the tympanic membrane; medially, by the lateral wall of the internal ear; it communicates, behind, with the tympanic antrum and through it with the mastoid air-cells, and in front with the pharyngotympanic tube (fig. 1046).

Fig. 1049.—An oblique section through the left temporal bone, to show the lateral wall of the middle ear, and the tympanic antrum.



The **roof** of the tympanic cavity is formed by a thin plate of bone, named the *tegmen tympani*, which separates the cranial and tympanic cavities, and forms the greater part of the anterior surface of the petrous portion of the temporal bone; it is prolonged backwards so as to roof the tympanic antrum, and forwards to cover the canal for the Tensor tympani muscle.

The **floor** is narrow, and consists of a thin, convex plate of bone which separates the tympanic cavity from the superior bulb of the internal jugular vein; in places this bony wall may be deficient, and then the tympanic cavity is separated from the vein by mucous membrane and fibrous tissue only. In the floor of the tympanic cavity, near the medial wall, there is a small aperture for the passage of the tympanic branch of the glossopharyngeal nerve.

The **lateral wall** of the tympanic cavity (fig. 1049) is formed mainly by the tympanic membrane, but partly by the ring of bone in which this membrane is attached. There is a deficiency or notch in the upper part of the ring, close to which are three small apertures, viz.: the anterior and posterior canaliculi for the chorda tympani nerve and the petrotympanic fissure.

The *posterior canaliculus for the chorda tympani nerve* is situated in the angle of junction between the posterior and lateral walls of the tympanic cavity

immediately behind the tympanic membrane and on a level with the upper end of the manubrium mallei; it leads into a minute canal, which descends in front of the canal for the facial nerve, and ends in that canal about 6 mm. above the stylomastoid foramen. Through it the chorda tympani nerve and a branch of the stylomastoid artery enter the tympanic cavity.

The *petrotympanic fissure* opens just above and in front of the ring of bone into which the tympanic membrane is inserted; in this situation it is a mere slit about 2 mm. in length. It lodges the anterior process and anterior ligament of the malleus, and transmits to the tympanic cavity the anterior tympanic branch of the (internal) maxillary artery.

The *anterior canaliculus for the chorda tympani nerve* is placed at the medial end of the petrotympanic fissure; through it the chorda tympani nerve leaves the tympanic cavity.

FIG. 1050.—The membranous wall of the right tympanic cavity. (Testut.)

The malleus has been resected immediately below its lateral process in order to show the malleolar folds and the pars flaccida.
1. Tympanic membrane. 2. Umbo. 3. Handle of malleus; 4. its cut surface. 5. Anterior malleolar fold. 6. Posterior malleolar fold. 7. Pars flaccida. 8, 9. Anterior and posterior recesses of tympanic membrane. 10. Fibrocartilaginous ring. 11. Petrotympanic fissure. 12. Pharyngotympanic tube. 13. Posterior canaliculus for chorda tympani. 14. Anterior canaliculus for chorda tympani. 15. Fossa incudis for short process of the incus. 16. Prominentia styloidea.

The **tympanic membrane** (figs. 1048, 1050) separates the tympanic cavity from the external auditory meatus. It is thin and semitransparent, nearly oval in form, somewhat broader above than below, and placed very obliquely, forming an angle of about fifty-five degrees with the floor of the meatus. Its longest diameter is downwards and forwards, and measures from 9 to 10 mm.; its shortest diameter from 8 to 9 mm. The greater part of its circumference is thickened, and forms a *fibrocartilaginous ring* which is fixed in the *tympanic sulcus* at the medial end of the meatus. This sulcus is deficient superiorly, and from the ends of the notch two bands, termed the *anterior* and *posterior malleolar folds*, are prolonged to the lateral process of the malleus. The small, somewhat triangular part of the membrane situated above these folds is lax and thin, and is named the *pars flaccida*; a small orifice is sometimes seen in it. The chief part of the membrane is taut and is named the *pars tensa*. The manubrium of the malleus is firmly attached to the inner surface of the tympanic membrane as far as its centre, which projects towards the tympanic cavity; the inner surface of the membrane is thus convex, and the point of greatest convexity is named the *umbo*. Although the membrane as a whole is convex on its inner surface, its radiating fibres (*vide infra*) are curved with their concavities directed inwards, and the membrane has a shape somewhat resembling that of a convolvulus flower.

Structure.—The tympanic membrane is composed of three strata: an outer (cuticular), an intermediate (fibrous), and an inner (mucous). The *cuticular layer* is derived from the skin which lines the external auditory meatus, and consists of stratified epithelium. The *fibrous stratum* consists of two layers: a superficial layer of radiate fibres which diverge from the manubrium of the malleus, and a deep layer of circular fibres, which are plentiful around the circumference, but sparse and scattered near the centre, of the membrane. Branched or dendritic fibres (Grüber) are also present, especially in the posterior half of the membrane. The *mucous layer* is a part of the mucous membrane of the tympanic cavity; it is thickest towards the upper part of the membrane, and is covered by a single layer of flattened cells. In the flaccid part of the tympanic membrane the fibrous stratum is replaced by loose connective tissue.

Vessels and Nerves.—The *arteries* of the tympanic membrane are derived from the deep auricular branch of the (internal) maxillary artery, which ramifies beneath the cuticular stratum; and from the stylomastoid branch of the posterior auricular artery, and tympanic branch of the maxillary artery, which are distributed to the mucous surface. The superficial *veins* open into the external jugular vein; those on the deep surface drain partly into the transverse sinus and veins of the dura mater, and partly into the plexus of veins on the pharyngotympanic (auditory) tube. The membrane receives its *nerve-supply* from the auriculotemporal branch of the mandibular nerve, the auricular branch of the vagus nerve, and the tympanic branch of the glossopharyngeal nerve.

The **medial wall** (fig. 1051) of the tympanic cavity is formed by the lateral wall of the internal ear. It presents for examination the promontory, the fenestra vestibuli, the fenestra cochleæ and the prominence of the facial nerve canal.

The *promontory* is a rounded prominence furrowed by small grooves which lodge the nerves of the tympanic plexus. It is formed by the projection outwards of the first turn of the cochlea. A minute spicule of bone frequently connects the promontory to the pyramid on the posterior wall.

The *fenestra vestibuli* is a reniform opening, situated above and behind the promontory, and leading from the tympanic cavity into the vestibule of the internal ear; its long diameter is horizontal, and its convex border is directed upwards. In the recent state it is occupied by the base of the stapes, the circumference of which is fixed to the margin of the fenestra by the annular ligament.

The *fenestra cochleæ* is situated below and a little behind the fenestra vestibuli, from which it is separated by the posterior part of the promontory. It lies completely under cover of the overhanging edge of the promontory, in a deep hollow or niche. It is placed very obliquely, and, in the macerated bone, opens upwards and forwards from the tympanic cavity into the scala tympani of the cochlea. In the recent state it is closed by the *secondary tympanic membrane*, which is somewhat concave towards the tympanic cavity and convex towards the cochlea, the membrane being bent so that its posterosuperior one-third forms an angle with its antero-inferior two-thirds. This membrane consists of three layers: an external, derived from the mucous lining of the tympanic cavity; an internal, from the lining membrane of the cochlea; and an intermediate, fibrous, layer.

The *prominence of the facial nerve canal* indicates the position of the upper part of the bony canal in which the facial nerve is contained; this canal, the wall of which may be partly deficient, traverses the medial wall of the tympanic cavity from before backwards, immediately above the fenestra vestibuli, and then curves downwards in the posterior wall.

The **posterior wall** of the tympanic cavity is wider above than below, and presents for examination the entrance to the tympanic antrum, the pyramid and the fossa incudis.

The *aditus to the tympanic antrum* is a large irregular aperture, which leads backwards from the epitympanic recess into the upper part of an air-sinus, named the *tympanic antrum* (p. 297). On the medial wall of the entrance to the antrum there is a rounded eminence, situated above and behind the prominence of the facial nerve canal; it corresponds with the position of the lateral semicircular canal.

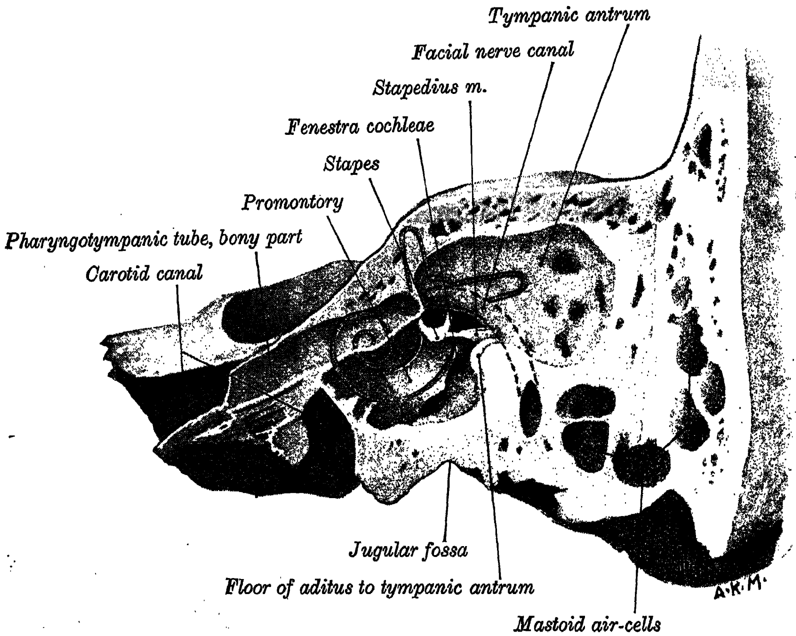
The *pyramid* is situated immediately behind the fenestra vestibuli, and in front of the vertical portion of the facial nerve canal; it is hollow, and contains the Stapedius muscle; its summit projects forwards towards the fenestra vestibuli, and is pierced by a small aperture which transmits the tendon of the muscle. The cavity in the pyramid is prolonged downwards and backwards in front of the facial nerve canal, and communicates with the latter by a minute aperture which transmits a twig from the facial nerve to the Stapedius muscle.

The *fossa incudis* is a small depression in the lower and posterior part of the epitympanic recess; it lodges the short process of the incus, which is fixed to the fossa by ligamentous fibres.

The *tympanic antrum* is a small air-sinus in the posterior portion of the petrous part of the temporal bone, communicating with the epitympanic

recess through the aditus, which is placed in the *upper* part of its anterior wall. Its diameters do not often exceed 10 mm., but its topographical relations are of great importance to the surgeon. Its *lateral wall* is formed by the post-meatal process of the squamous part of the temporal bone and corresponds to the suprameatal triangle on the outer surface of the skull. This wall is only 2 mm. thick in the newly-born child but it usually averages 10-12 mm. in the adult. *Posteriorly* the antrum is related to the sigmoid sinus, but some of the mastoid air-cells may intervene between them. *Superiorly* the roof is formed by the tegmen tympani, which separates the antrum from the middle cranial

FIG. 1051.—An oblique section through the left temporal bone, to show the medial wall of the middle ear.



The cochlea and the superior and lateral semicircular canals are outlined in *blue*. Note the relationship of the first coil of the cochlea to the promontory, and the relationships of the facial nerve canal and the lateral semicircular canal to the medial wall of the aditus.

fossa and the temporal lobe of the brain. *Inferiorly* the floor shows a number of apertures which communicate with the mastoid air-cells. These air-cells vary considerably in number, size and form, and, like the tympanic antrum, are lined by mucous membrane continuous with that lining the tympanic cavity.

The **anterior wall** of the tympanic cavity is constricted owing to the approximation of the medial and lateral walls of the cavity. Its lower and larger part consists of a thin lamina of bone which forms the posterior wall of the carotid canal, and is perforated by the superior and inferior caroticotympanic nerves, and the tympanic branch of the internal carotid artery. At the upper part of the anterior wall there are two canals, placed one above the other; the higher is the *canal for the Tensor tympani muscle*, the lower, the *bony part of the pharyngotympanic* (*auditory*) *tube*. These canals incline downwards and forwards, and open in the angle between the squamous and petrous parts of the temporal bone; they are separated by a thin, bony septum. The canal for the Tensor tympani and the septum run backwards on the medial wall of the tympanic cavity, and end immediately above the fenestra vestibuli, where the posterior end of the septum is curved laterally to form a pulley, named the processus cochleariformis, over which the tendon of the Tensor tympani bends

in a lateral direction to reach its insertion into the upper part of the manubrium mallei.

The **pharyngotympanic tube** (auditory tube) is the channel through which the tympanic cavity communicates with the nasal part of the pharynx. Its length is about 36 mm., and its direction is downwards, forwards and medially, forming an angle of about 45° with the sagittal plane and one of about 30° with the horizontal plane, It is formed partly of bone, partly of cartilage and fibrous tissue (fig. 1046).

The *bony part* of the tube is about 12 mm. long. It begins in the anterior wall of the tympanic cavity, and, gradually narrowing, ends at the angle of junction of the squamous and petrous portions of the temporal bone, its extremity presenting a jagged margin which serves for the attachment of the cartilaginous part; the carotid canal lies on its medial side. It is oblong in transverse section with its greater diameter from side to side.

The *cartilaginous part* of the tube, about 24 mm. long, is formed of a triangular plate of cartilage, the greater part of which is situated in the posteromedial wall of the tube. The apex of the fibrocartilage is attached by fibrous tissue to the circumference of the medial end of the bony part of the tube, while its base lies directly under the mucous membrane of the lateral wall of the nasal part of the pharynx, where it forms an elevation, known as the *tubal elevation*, behind the pharyngeal orifice of the tube. The upper part of the cartilage is bent laterally and downwards, and the cartilage therefore consists of a broad medial *lamina*, and a narrow lateral *lamina*. On transverse section the cartilage has the appearance of a hook; the groove or furrow produced by the bending of the cartilage is open below and laterally, and this part of the wall of the canal is completed by fibrous membrane. The cartilage is fixed to the base of the skull in a groove between the petrous part of the temporal bone and the greater wing of the sphenoid bone; this groove ends near the root of the medial pterygoid plate. The cartilaginous and bony parts of the tube are not in the same plane, the former inclining downwards a little more than the latter. The diameter of the tube is greatest at the pharyngeal orifice, least at the junction of the bony and cartilaginous portions, and again increased towards the tympanic cavity; the narrowest part of the tube is termed the *isthmus*.

Anterolaterally the Tensor palati muscle separates the tube from the otic ganglion, the mandibular nerve and its branches, the chorda tympani nerve and the middle meningeal artery. This muscle receives some fibres from the lateral lamina of the cartilage and from the membranous part of the tube; these fibres constitute the *Dilatator tubæ* muscle. Postero-medially the tube is related to the petrous part of the temporal bone and to the Levator palati muscle, which arises partly from its medial lamina. The position and relations of the pharyngeal orifice are described with the nasal part of the pharynx (p. 1290).

The mucous membrane of the tube is continuous in front with that of the pharynx, and behind with that of the tympanic cavity; it is covered with ciliated columnar epithelium and is thin in the bony part, while in the cartilaginous part it contains many mucous glands, and near the pharyngeal orifice a considerable amount of adenoid tissue, named by Gerlach the *tube-tonsil*.

The tube is opened during deglutition by the Salpingopharyngeus and Dilatator tubæ muscles. H. Blakeway * is of opinion that contraction of the Tensor palati is more likely to produce closure than opening of the tube.

In the new-born child the pharyngotympanic tube is about half as long as that of the adult. Its direction is more horizontal, and its bony part is relatively shorter, but much wider than in the adult. Its pharyngeal orifice is a narrow slit, which is on a level with the palate and is devoid of a tubal elevation.

Vessels and Nerves.—The *arteries* of the pharyngotympanic tube are derived from the ascending pharyngeal branch of the external carotid artery and from two branches of the (internal) maxillary artery, viz. :—the middle meningeal artery and the artery of the

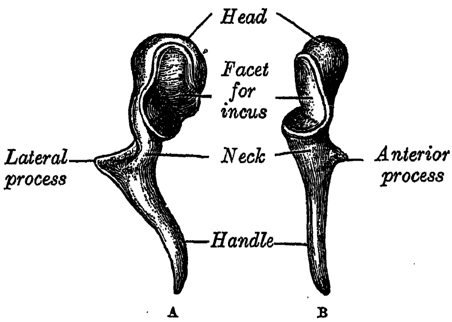
* *Journal of Anatomy and Physiology*, vol. xlviii.

pterygoid canal. The *veins* open into the pterygoid venous plexus. The *nerves* of the tube spring from the pharyngeal plexus and from the pharyngeal branch of the sphenopalatine ganglion.

The Auditory Ossicles

The tympanic cavity contains a chain of three movable ossicles, the *malleus*, *incus*, and *stapes*, the development of which is described on p. 99. The malleus is attached to the tympanic membrane, the base of the stapes to the circumference of the fenestra vestibuli, while the incus is placed between, and articulates with, the malleus and stapes.

Fig. 1052.—The left malleus. A. From behind. B. From the medial side.



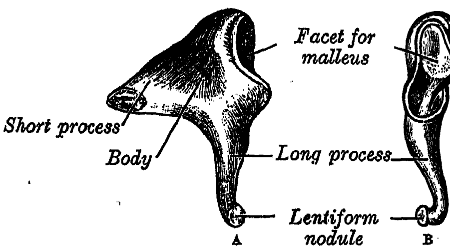
The **malleus** (fig. 1052), so named from its fancied resemblance to a hammer, is from 8 to 9 mm. long, and is the largest of the auditory ossicles. It consists of a head, neck and three processes, viz. the manubrium or handle, and the anterior and lateral processes.

The *head*, which is the large upper end of the bone, is situated within the epitympanic recess; it is ovoid in shape, and articulates posteriorly with the incus, being free in the rest of its extent. The facet for articulation with the incus is constricted near the middle, and consists of an upper larger and lower smaller part, situated nearly at right angles to each other. Opposite the constriction the lower margin of the facet projects in the form of a process, which is named the *cog-tooth* or *spur* of the malleus.

The *neck* is the contracted part just beneath the head; below the neck there is an enlargement to which the various processes are attached.

The *handle of the malleus* is connected by its lateral margin with the tympanic membrane. It is directed downwards, medially and backwards; it decreases in size towards its free end, which is curved slightly forwards and flattened transversely. Near the upper end of its medial surface there is a slight projection, into which the tendon of the Tensor tympani is inserted.

Fig. 1053.—The left incus. A. From the medial side. B. From the front.



The *anterior process* is a delicate spicule, directed forwards from the enlargement below the neck; it is connected to the petrotympanic fissure by ligamentous fibres. In the fœtus this is the longest process of the malleus, and it is continuous in front with the cartilage of Meckel (p. 99).

The *lateral process* is a conical projection which springs from the root of the handle of the malleus; it is directed laterally, and is attached to the upper part of the tympanic membrane and, by means of the anterior and posterior malleolar folds, to the extremities of the notch at the upper part of the tympanic sulcus.

Ossification.—The malleus, with the exception of its anterior process, is ossified from a single centre, which appears near the neck of the bone. The anterior process is ossified separately, in membrane, and joins the main part of the bone about the sixth month of fœtal life.

The **incus** (fig. 1053) has received its name from its supposed resemblance to an anvil, but its shape is more like that of a premolar tooth, with two widely diverging roots. It consists of a body and two processes.

The *body* is somewhat cubical, but compressed laterally. On its anterior

surface there is a saddle-shaped facet, for articulation with the head of the malleus.

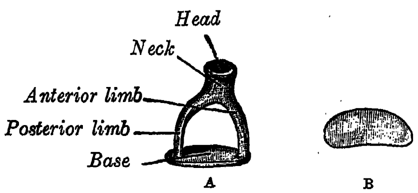
The *long process*, rather more than half the length of the handle of the malleus, descends nearly vertically, behind and parallel to that process ; its lower end bends medially, and terminates in a rounded projection, named the *lentiform nodule*, the inner surface of which is covered with cartilage, and articulates with the head of the stapes.

The *short process*, somewhat conical in shape, projects backwards, and is attached by ligamentous fibres to the fossa incudis, in the lower and posterior part of the epitympanic recess.

Ossification.—The incus is ossified from one centre, which appears in the upper part of its long process ; the lentiform nodule may have a separate centre.

The **stapes** (fig. 1054), so called from its resemblance to a stirrup, consists of a head, neck, two limbs and a base.

FIG. 1054.—A. The left stapes. B. Medial surface of the base of the stapes.



The *head* is directed laterally, and on it there is a depression for articulation with the lentiform nodule of the incus.

The *neck* is the constricted part supporting the head ; the tendon of the Stapedius muscle is inserted into its posterior surface.

The *limbs* diverge from the neck and are connected at their ends by a flattened oval plate, termed the *base*, which forms the footplate of the stirrup and is fixed to the margin of the fenestra vestibuli by a ring of ligamentous fibres. The anterior limb is shorter and less curved than the posterior.

Ossification.—The stapes is ossified from a single centre, which appears in the base of the bone.

The articulations of the auditory ossicles.—The incudomalleolar joint is a saddle articulation. The incudostapedial joint is a ' ball-and-socket ' articulation. Each is enveloped by an articular capsule.

The ligaments of the ossicles.—The ossicles are connected to the walls of the tympanic cavity by ligaments : three for the malleus, and one each for the incus and stapes.

The *anterior ligament of the malleus* is attached by one end to the neck of the malleus, just above the anterior process, and by the other to the anterior wall of the tympanic cavity, close to the petrotympanic fissure, some of its fibres being prolonged through the fissure to reach the spine of the sphenoid bone.

The *lateral ligament of the malleus* is a triangular band passing from the posterior part of the border of the tympanic notch to the head of the malleus. Helmholtz described the anterior ligament and the posterior part of the lateral ligament as forming together the ' axis ligament ' around which the malleus rotates.

The *superior ligament of the malleus* connects the head of the malleus to the roof of the epitympanic recess.

The *posterior ligament of the incus* connects the end of the short process of the incus to the fossa incudis.

A *superior ligament of the incus* has been described, but it is little more than a fold of mucous membrane.

The vestibular surface and the circumference of the base of the stapes are covered with hyaline cartilage ; that encircling the base is attached to the margin of the fenestra vestibuli by a ring of elastic fibres, termed the *annular ligament of the base of the stapes*. The posterior part of this ligament is much narrower than the anterior part, and acts as a kind of hinge on which the base of the stapes moves when the Stapedius muscle contracts.

The **muscles of the tympanic cavity** are the Tensor tympani and Stapedius.

The **Tensor tympani** (fig. 1046) is contained in the bony canal above the bony part of the pharyngotympanic (auditory) tube, from which it is separated by a thin bony septum. It arises from the cartilaginous portion of the pharyngotympanic tube and the adjoining part of the greater wing of the sphenoid, as well as from the bony canal in which it is contained. Passing backwards through the canal, it ends in a slender tendon which bends laterally round the pulley-like processus cochleariformis, and is inserted into the handle of the malleus, near its root.

Nerve-supply.—The Tensor tympani is supplied by a branch of the mandibular nerve through the otic ganglion.

The **Stapedius** arises from the wall of a conical cavity in the pyramid; its tendon emerges from the orifice at the apex of the eminence, and, passing forwards, is inserted into the posterior surface of the neck of the stapes.

Nerve-supply.—The Stapedius is supplied by a branch of the facial nerve.

Actions.—Under normal conditions, the Tensor tympani and the Stapedius contract simultaneously and reflexly in response to sounds of fairly high intensity, exerting "a protective damping effect upon sound vibrations reaching the internal ear." *

Movements of the auditory ossicles.—The handle of the malleus follows all the movements of the tympanic membrane, while the malleus and incus rotate together around an axis which runs through the short process of the incus and the anterior ligament of the malleus. When the tympanic membrane and the handle of the malleus move inwards, the long process of the incus also moves in the same direction and pushes the base of the stapes towards the labyrinth. This motion is communicated to the fluid (perilymph) contained within the labyrinth and the movement of the perilymph causes an outward bulging of the secondary tympanic membrane, which closes the fenestra cochleæ. The conditions are reversed when the tympanic membrane moves in an outward direction, but if this movement of the membrane be exaggerated the incus does not follow the full outward excursion of the malleus, but merely glides on this bone at the incudomalleolar joint, and thus the danger of pulling the foot of the stapes out of the fenestra vestibuli is avoided. When the handle of the malleus is carried inwards, the cog-tooth or spur on the lower margin of the head of the malleus locks the incudomalleolar joint, and this necessitates an inward movement of the long process of the incus; the joint is unlocked when the handle of the malleus is carried outwards.

The **mucous membrane** of the tympanic cavity is continuous with that of the pharynx, through the pharyngotympanic (auditory) tube. It invests the auditory ossicles and the muscles and nerves contained in the tympanic cavity, forms the inner layer of the tympanic membrane, and the outer layer of the secondary tympanic membrane, and lines the tympanic antrum and mastoid air-cells. It forms several vascular folds which extend from the walls of the tympanic cavity to the ossicles; of these, one descends from the roof of the cavity to the head of the malleus and upper margin of the body of the incus, and a second invests the Stapedius muscle; other folds invest the chorda tympani nerve and the Tensor tympani muscle. These folds separate off pouch-like recesses, and give the interior of the tympanum a somewhat honeycombed appearance. One of these pouches, termed the *superior recess of the tympanic membrane*, lies between the neck of the malleus and the membrana flaccida. Two other recesses, termed the *anterior* and *posterior recesses of the tympanic membrane*, may be mentioned: they are formed by the mucous membrane which envelops the chorda tympani nerve, and are situated, one in front of, and the other behind, the handle of the malleus. In the tympanic cavity the mucous membrane is pale, thin, slightly vascular, and covered with cubical epithelial cells, except around the orifice of the pharyngotympanic tube, where the cells are ciliated. There are no mucous glands in the tympanic cavity. The tympanic antrum and the mastoid air-cells are lined by a non-ciliated epithelium, which is squamous in character.

Vessels and Nerves.—The *arteries* are six in number. Two of them are larger than the others, viz. the anterior tympanic branch of the (internal) maxillary artery, which supplies the tympanic membrane, and the stylomastoid branch of the posterior auricular artery, which supplies the posterior part of the tympanic cavity and mastoid air-cells. The smaller arteries are—the superficial petrosal branch of the middle meningeal artery, which enters through the hiatus for the greater superficial petrosal nerve; the superior tympanic branch of the middle meningeal artery, which traverses the canal for the Tensor tympani; a branch from the ascending pharyngeal artery, and another from the artery of the pterygoid canal, which accompany the pharyngotympanic tube; and the tympanic branch from the internal carotid artery, given off in the carotid canal and perforating the thin anterior wall of the tympanic cavity. The *veins* terminate in the pterygoid venous plexus and in the superior petrosal sinus. From the mucous membrane of the tympanic antrum a small group of veins runs medially through the arch formed by the superior semicircular canal. They emerge on the posterior surface of the petrous part of the temporal bone through the subarcuate fossa, and open into the superior petrosal sinus. These small veins are the remains of the large subarcuate veins of the child, and constitute a pathway of infection

* C. S. Hallpike, "On the Function of the Tympanic Muscles," *Proc. Roy. Soc. Med.*, 1935, vol. xxviii.

from the tympanic antrum to the meninges of the brain. The *nerves* constitute the tympanic plexus, which ramifies upon the surface of the promontory. The plexus is formed by (1) the tympanic branch of the glossopharyngeal nerve, and (2) the caroticotympanic nerves.

The *tympanic branch of the glossopharyngeal* enters the tympanic cavity by the *canaliculus for the tympanic nerve,* and divides into branches which ramify on the promontory and enter into the formation of the tympanic plexus. The *superior and inferior caroticotympanic nerves,* from the carotid plexus of the sympathetic, pass through the wall of the carotid canal, and join the plexus. The tympanic plexus supplies, (*a*) branches to the mucous lining of the tympanic cavity, pharyngotympanic tube, and mastoid air-cells; (*b*) a branch which goes through an opening in front of the fenestra vestibuli and joins the greater superficial petrosal nerve; and (*c*) the *lesser superficial petrosal nerve,* which may be looked upon as the continuation of the tympanic branch of the glossopharyngeal nerve through the tympanic plexus. The lesser superficial petrosal nerve traverses a small canal below the canal for the Tensor tympani, runs past, and receives a connecting branch from, the ganglion of the facial nerve, and reaches the anterior surface of the temporal bone through a small opening on the lateral side of the hiatus for the greater superficial petrosal nerve. It then passes through the foramen ovale or the canaliculus innominatus (p. 291 *) and joins the otic ganglion (p. 1054).

The *chorda tympani nerve* crosses the tympanic cavity. It is given off from the facial nerve, about 6 mm. before that nerve emerges from the stylomastoid foramen. It runs upwards and forwards in a canal, and enters the tympanic cavity through the *posterior canaliculus,* and becomes invested with mucous membrane. It traverses the tympanic cavity, crossing medial to the tympanic membrane and the upper part of the handle of the malleus to the anterior wall, where it emerges through the *anterior canaliculus.*

Applied Anatomy.—Fractures of the middle fossa of the base of the skull almost invariably involve the tympanic roof, and are accompanied by a rupture of the tympanic membrane or fracture through the roof of the bony meatus. They are associated with profuse continued bleeding from the ear, and, if the dura mater has also been torn, with discharge of copious amounts of cerebrospinal fluid.

The tympanic cavity is very frequently the seat of disease, both suppurative and non-suppurative, and in practically every case the inflammation spreads upwards from the nose or throat along the pharyngotympanic tube. Acute inflammatory troubles spreading up to the tympanic cavity are usually associated with so much inflammatory swelling of the mucous membrane of the tube as to occlude it, and thus the products of inflammation are pent up in the tympanic cavity and directly involve the tympanic antrum. In such circumstances the only means of escape for the products is by rupture of the tympanic membrane, which usually occurs spontaneously and is followed by a free discharge of pus, with relief from the acute pain which exists in this condition. Should the swelling of the walls of the pharyngotympanic tube then subside, the normal drainage of the cavity will be established and the perforation in the drum will heal, but if not—as is often the case because the opening of the tube may be occluded by adenoid growths in the nasal part of the pharynx or other cause—the pus will continue to accumulate in the middle ear and will overflow through the perforation as a chronic otorrhœa. Several intracranial complications are often produced owing to purulent material being retained; thus an abscess may form between the bone and dura mater, (*a*) above the roof of the tympanic cavity, and immediately beneath the dura covering the temporal lobe of the brain, or (*b*) between the deep aspect of the mastoid process and the sigmoid sinus, possibly extending widely and surrounding the sinus. In this latter type of case thrombosis of the sinus readily occurs, and the clot being also infected tends to disintegrate and be carried into the general circulation, particles becoming lodged in the capillaries of the lungs and setting up abscesses therein. Pyæmia from sigmoid sinus thrombosis is more common than from any other focus of origin. In addition, bone disease of the tympanic cavity or antrum may be associated with severe and fatal septic meningitis, or with the formation of abscess in the brain, the most common sites being the temporal lobe and the hemisphere of the cerebellum.

In many cases of chronic bone disease in the tympanic cavity, the facial nerve becomes exposed as it lies in its canal and an inflammatory process is set up in the nerve, leading to facial paralysis of the infranuclear type (p. 1064).

In dealing with suppuration in the tympanum by operation, the tympanic antrum is first reached through the suprameatal triangle (p. 252), the posterior wall of the external auditory meatus being the direction which is taken. In enlarging the opening from the antrum to the tympanum, the facial nerve may be protected by passing a special probe through the passage, and only removing the bone from the lateral side. In the child the tympanic antrum is close to the surface, and the facial nerve is not covered by the mastoid process.

The Internal Ear

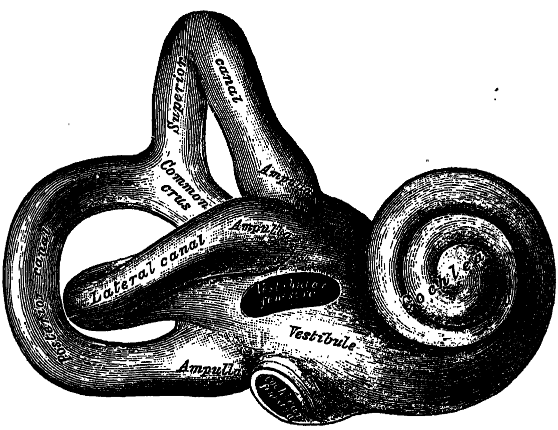
The **internal ear** is the essential part of the organ of hearing. It consists of two parts: (*a*) the *bony labyrinth*, a series of cavities within the petrous part of the temporal bone, and (*b*) the *membranous labyrinth*, a series of communicating membranous sacs and ducts, contained within the bony cavities.

The Bony Labyrinth (figs. 1055, 1056)

The **bony labyrinth** consists of three parts: the *vestibule*, the *semicircular canals* and the *cochlea*. These are cavities hollowed out of the substance of the bone, and lined by periosteum; they contain a clear fluid, known as the perilymph, in which the membranous labyrinth is placed.

The **vestibule** is the central part of the bony labyrinth, and is situated medial to the tympanic cavity, behind the cochlea and in front of the semicircular canals. It is somewhat ovoid in shape, but flattened transversely; it measures about 5 mm. from before backwards, the same from above downwards, and about 3 mm. across. In its *lateral wall* there is the opening of the fenestra vestibuli, closed in the recent state by the base of the stapes and its annular ligament. On the front part of the *medial wall* there is a small *spherical recess*, which lodges the saccule, and is perforated by several minute holes (*macula cribrosa media*). The recess corresponds to the inferior vestibular area in the bottom of the internal auditory meatus, and the foramina transmit filaments of the auditory nerve to the saccule. Behind this recess there is an oblique ridge, termed the *vestibular crest*, the anterior end of which is named the *pyramid of the vestibule*; this ridge divides below to enclose a small depression [the *cochlear recess*], which is perforated by a number of holes for the passage of filaments of the auditory nerve to the vestibular end of the duct of the cochlea. Above and behind the vestibular crest, and situated in the *roof* and medial wall of the vestibule there is an *elliptical recess* which lodges the utricle. The pyramid and adjoining part of the recessus ellipticus are perforated by a number of holes [*macula cribrosa superior*]; the holes in the pyramid transmit the nerves to the utricle, and those in the recessus ellipticus the nerves to the ampullæ of the superior and lateral semicircular ducts. The pyramid and the adjoining part of the elliptical recess correspond to the superior vestibular area at the bottom of the internal auditory meatus. The orifice of the *aqueduct of the vestibule* lies below the recessus ellipticus. This aqueduct extends to the posterior surface of the petrous portion of the temporal bone; it transmits a small vein, and contains a tubular prolongation of the membranous labyrinth which is termed the *ductus endolymphaticus*. At the *posterior part* of the vestibule there are the five orifices of the semicircular canals: at the *anterior part*, an elliptical opening leading into the scala vestibuli of the cochlea.

Fig. 1055.—The right osseous labyrinth. Lateral aspect.



The **semicircular canals** are three in number, superior, posterior and lateral, and are situated above and behind the vestibule. They are compressed from side to side, and each describes about two-thirds of a circle. They are unequal in length, but are about 0·8 mm. in diameter and each presents a dilatation at one end, called the *ampulla*, the diameter of which is nearly twice that of the

canal. They open into the vestibule by five orifices, one of which is common to two of the canals.

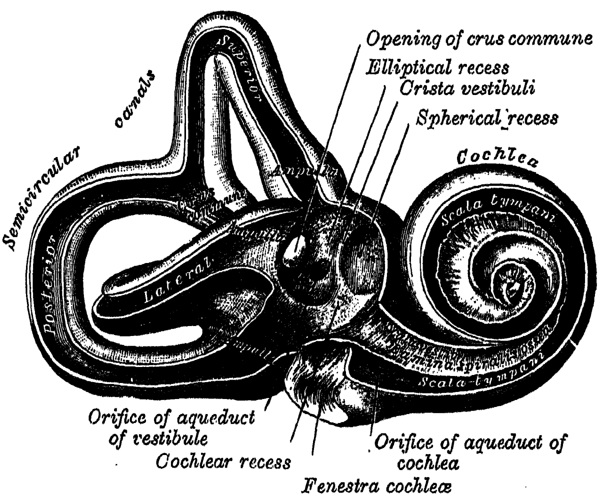
The *superior semicircular canal*, 15 to 20 mm. in length, is vertical in direction, and is placed transversely to the long axis of the petrous portion of the temporal bone, on the anterior surface of which its arch forms the arcuate eminence. Its anterolateral end is ampullated, and opens into the upper and lateral part of the vestibule ; the opposite end unites with the upper end of the posterior canal to form the *crus commune*, which is about 4 mm. long, and opens into the medial part of the vestibule.

The *posterior semicircular canal*, also vertical, is directed backwards, nearly parallel with the posterior surface of the petrous bone ; it is from 18 mm. to 22 mm. long ; its ampullated end opens into the lower part of the vestibule, where there are several small holes [*macula cribrosa inferior*] for the transmission of the nerves to this ampulla, their position corresponding to the foramen singulare in the bottom of the internal auditory meatus. Its upper end opens into the crus commune.

The *lateral* or *horizontal canal* is from 12 mm. to 15 mm. long, and its arch is directed horizontally backwards and laterally. Its anterior or ampullated end opens into the upper and lateral angle of the vestibule, just above the fenestra vestibuli and immediately below the ampullated end of the superior canal; its posterior end opens below the orifice of the crus commune.

The lateral semicircular canal of one ear is in the same plane as that of the other ear ; while the superior canal of one ear is in a plane parallel with that of the posterior * canal of the other ear.

FIG. 1056.—The interior of the right osseous labyrinth.



The cochlea (figs. 1056, 1057) bears a resemblance to the shell of the common snail ; it forms the anterior part of the labyrinth, is conical in form, and placed in front of the vestibule ; it measures about 5 mm. from base to apex, and its breadth across the base is about 9 mm. Its apex [or *cupola*] is directed forwards and laterally, with a slight inclination downwards, towards the upper and front part of the medial wall of the tympanic cavity; its base is directed towards the bottom of the internal auditory meatus, and is perforated by numerous apertures for the passage of the cochlear nerve. The cochlea † consists of a conical-shaped central axis, termed the *modiolus* ; of a canal, wound spirally around the central axis for two turns and three-quarters ; and of a delicate lamina, termed the *osseous spiral lamina*, which projects from the modiolus into the canal, and partially divides it. In the recent state the division of the canal is completed by the *basilar membrane*, which stretches from the free border of the osseous spiral lamina to the outer wall of the bony cochlea ; the two passages into which the cochlear canal is thus divided communicate with each other at the apex of the modiolus by a small opening, named the *helicotrema*.

The *modiolus* is the conical, central axis or pillar of the cochlea. Its base is broad, and appears at the bottom of the internal auditory meatus, where it corresponds with the tractus spiralis foraminosus, which is perforated by

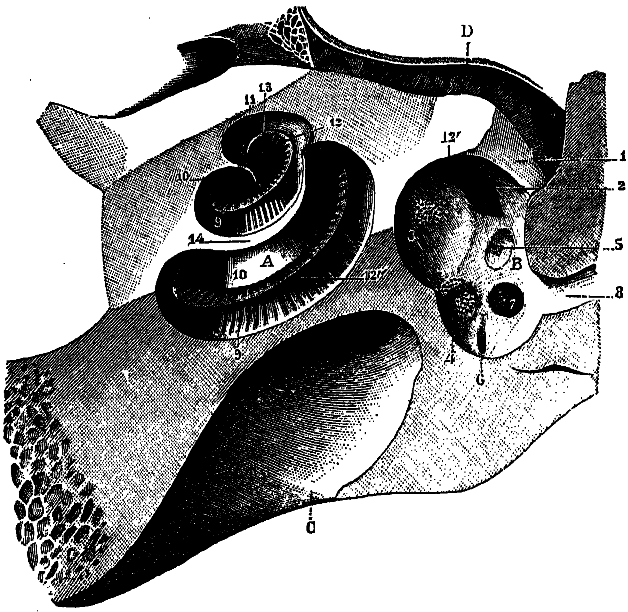
* E. W. Peet (*Proc. Phys. Society*, 1937) has recently shown that those planes are not actually parallel.

† In the description which follows, the cochlea is supposed to be resting on its base.

numerous orifices for the transmission of the branches of the cochlear nerve; the nerves for the first turn and a half of the cochlea pass through the foramina of the tractus spiralis foraminosus; those for the apical turn, through the foramen centrale. The canals of the tractus spiralis foraminosus pass through the modiolus and successively bend outwards to reach the attached margin of the osseous spiral lamina. Here they become enlarged, and by their apposition form the *spiral canal of the modiolus*, which follows the course of the attached margin of the osseous spiral lamina and lodges the spiral ganglion. The foramen centrale is continued into a canal which runs through the middle of the modiolus to its apex.

The bony canal of the cochlea takes two turns and three-quarters round the modiolus; the first turn bulges into the tympanic cavity and there gives rise to the promontory (p. 1197). It is about 30 mm. long, and diminishes gradually in diameter from the base to the summit, where it ends in the *cupola*, which forms the apex of the cochlea. The beginning of this canal is about 3 mm. in

FIG. 1057.—The cochlea and vestibule. Exposed from above. (Testut.)



All the hard parts which form the roof of the internal ear have been removed with the saw. A. Cochlea. B. Vestibule. C. Internal auditory meatus. D. Tympanic cavity. 1. Section of promontory. 2. Vestibular fissure. 3. Spherical recess. 4. Elliptical recess. 5. Cochlear recess. 6. Orifice of the aqueduct of the vestibule. 7. Inferior opening of the posterior semicircular canal. 8. Non-ampullated end of lateral semicircular canal. 9. Scala tympani of the cochlea. 10. Scala vestibuli. 11. Cupola. 12. Osseous spiral lamina, with 12′, its vestibular origin. 12″, its external border. 13. Helicotrema. 14. Bony wall of cochlea.

diameter, and in it there are three openings. One—the *fenestra cochleæ*—communicates with the tympanic cavity and in the recent state is closed by the *secondary tympanic membrane*; another, of an elliptical form, opens into the vestibule. The third is the aperture of the aqueduct of the cochlea, leading to a minute funnel-shaped canal which opens on the inferior surface of the petrous part of the temporal bone. It transmits a small vein to join the inferior petrosal sinus, and establishes a communication between the subarachnoid space and the scala tympani.

The *osseous spiral lamina* is a bony shelf or ledge which winds round and projects from the modiolus into the interior of the canal, like the thread of a screw. It reaches about halfway across the canal, and incompletely divides it into two passages or scalæ: an upper, named the *scala vestibuli*, and a lower, the *scala tympani*. The width of the osseous spiral lamina gradually decreases from the basal to the apical coil of the cochlea, and near the summit of the cochlea the lamina ends in a hook-shaped process, termed the *hamulus of the spiral lamina*; this assists in forming the boundary of the *helicotrema*, through which the two scalæ communicate with each other. From the spiral canal of the modiolus numerous canals pass outwards through the osseous spiral lamina as

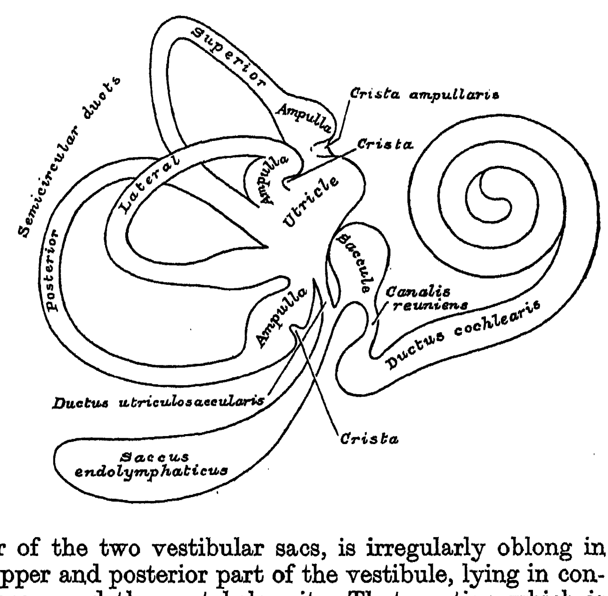
far as its free edge and transmit branches of the cochlear nerve. In the lower part of the first turn of the cochlea a *secondary spiral lamina* projects inwards from the outer wall of the bony tube; it does not, however, reach the osseous spiral lamina, so that if the laminæ be viewed from the vestibule a narrow fissure, termed the *vestibular fissure,* is seen between them.

The *bony labyrinth* is lined by a thin fibroserous membrane which is closely adherent to the bone; the free surface of the membrane is smooth, and covered with a layer of epithelium. The bony labyrinth is filled with *perilymph,* a fluid identical in composition, and confluent with, the cerebrospinal fluid. The part of the petrous bone which immediately surrounds the labyrinth is developed from the cartilaginous ear-capsule; it is denser than the rest of the petrous bone, and exhibits interglobular spaces, which contain cartilage cells (fig. 1061). The modiolus of the cochlea, on the other hand, is formed of spongy membrane-bone (Fraser and Dickie *). A tubular process of the lining membrane is prolonged through the aqueduct of the cochlea to the inner surface of the dura mater. The perilymphatic space of the vestibule communicates behind with that of the semicircular canals, and opens anteriorly into the scala vestibuli of the cochlea, which in turn opens into the scala tympani through the helicotrema, at the apex of the cochlea. The scala tympani is separated from the tympanic cavity by the secondary tympanic membrane, but is continuous with the subarachnoid space through the aqueduct of the cochlea.

The Membranous Labyrinth (figs. 1058 to 1060)

The membranous labyrinth is lodged within, but is smaller than the bony labyrinth; it is filled with fluid named *endolymph,* and in its walls the branches of the auditory nerve are distributed. It consists of: (*a*) the *utricle* and *saccule,* two small sacs, lodged in the vestibule; (*b*) three *semicircular ducts,* enclosed within the semicircular canals; and (*c*) the *duct of the cochlea,* contained within the bony cochlea. The various parts of the membranous labyrinth form a closed system of channels which, however, communicate freely with one another; the semicircular ducts open into the utricle, the utricle into the saccule through the ductus utriculosaccularis, and the saccule into the duct of the cochlea through the canalis reuniens.

Fig. 1058.—A schematic representation of the membranous labyrinth. (J. K. Milne Dickie.)



The membranous labyrinth is fixed at certain points to the wall of the bony labyrinth, but is separated from the greater part of the bony labyrinth by a space which contains the perilymph.

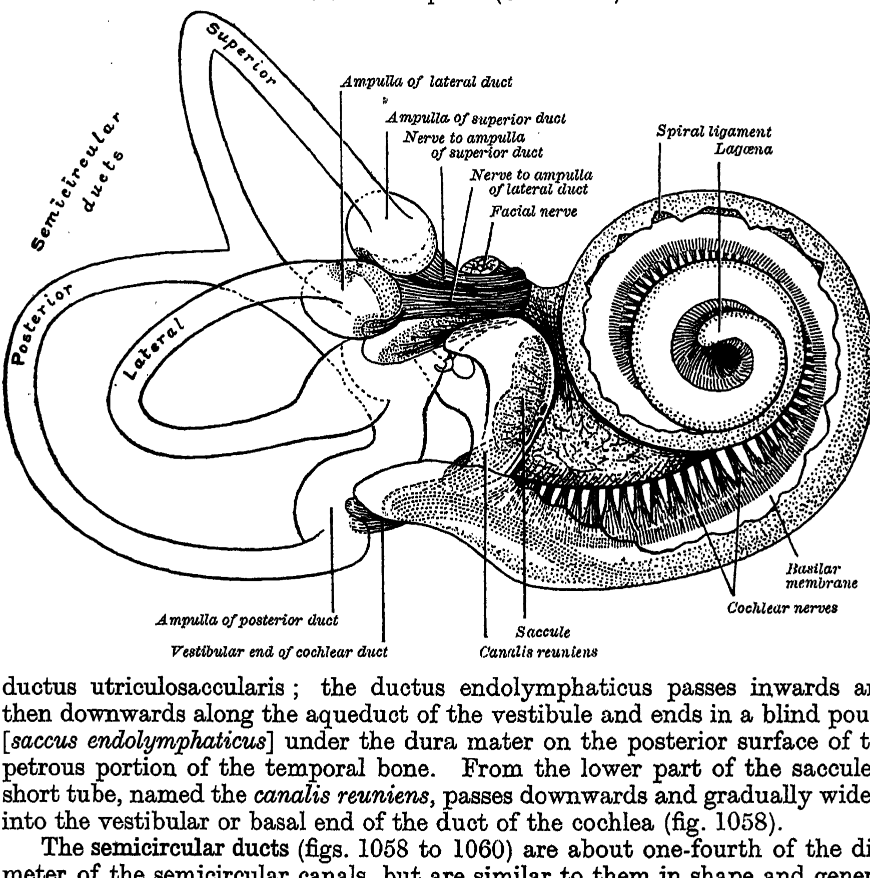
The **utricle**, the larger of the two vestibular sacs, is irregularly oblong in shape, and occupies the upper and posterior part of the vestibule, lying in contact with the elliptical recess and the part below it. That portion which is lodged in the elliptical recess forms a sort of pouch or cul-de-sac; the lateral half of the floor of this is thickened, and forms the *macula of the utricle,* which receives the utricular filaments of the auditory nerve. The ampullæ of the superior and lateral semicircular ducts open into the lateral part of the utricle, while the ampulla of the posterior duct, the crus commune and the posterior end of the lateral duct open into the medial part of the utricle. The posterior

* J. S. Fraser and J. K. Milne Dickie, *Journal of Anatomy and Physiology,* vol. xlix.

end of the lateral duct widens into a flattened cone which joins the medial end of the utricle at a right angle (Milne Dickie *). From its anteromedial part a fine canal, named the *ductus utriculosaccularis*, is given off, and opens into the ductus endolymphaticus.

The saccule lies in the spherical recess near the opening of the scala vestibuli of the cochlea. When seen from the front it presents a nearly globular form, but it is prolonged backwards in the form of a cone, the upper surface of which is in contact with the under surface of the utricle, and the utricle and saccule have here a common wall (Milne Dickie †). On its anterior wall there is an oval thickening, termed the *macula of the saccule* (fig. 1062), to which the saccular filaments of the auditory nerve are distributed. Its cavity communicates indirectly through a Y-shaped tube with that of the utricle. From its posterior part the *ductus endolymphaticus* is given off, and it is joined by the

FIG. 1059.—The right membranous labyrinth of a fifth-month human embryo. × 10. Anterolateral aspect. (G. Retzius.)



ductus utriculosaccularis ; the ductus endolymphaticus passes inwards and then downwards along the aqueduct of the vestibule and ends in a blind pouch [*saccus endolymphaticus*] under the dura mater on the posterior surface of the petrous portion of the temporal bone. From the lower part of the saccule a short tube, named the *canalis reuniens*, passes downwards and gradually widens into the vestibular or basal end of the duct of the cochlea (fig. 1058).

The semicircular ducts (figs. 1058 to 1060) are about one-fourth of the diameter of the semicircular canals, but are similar to them in shape and general form. Each has an ampulla at one end, viz. : the end which lies within the ampulla of the corresponding bony canal. The semicircular ducts open by five orifices into the utricle, one opening being common to the medial end of the superior, and the upper end of the posterior, duct. In each of the ampullæ the wall is thickened, and projects into the cavity as a transverse elevation shaped somewhat like the figure 8, and named the *septum transversum* ; the most prominent part of this septum is termed the *crista ampullaris*.

The utricle, saccule and semicircular ducts are held in position by fibrous bands which stretch across the perilymphatic space to the bony walls.

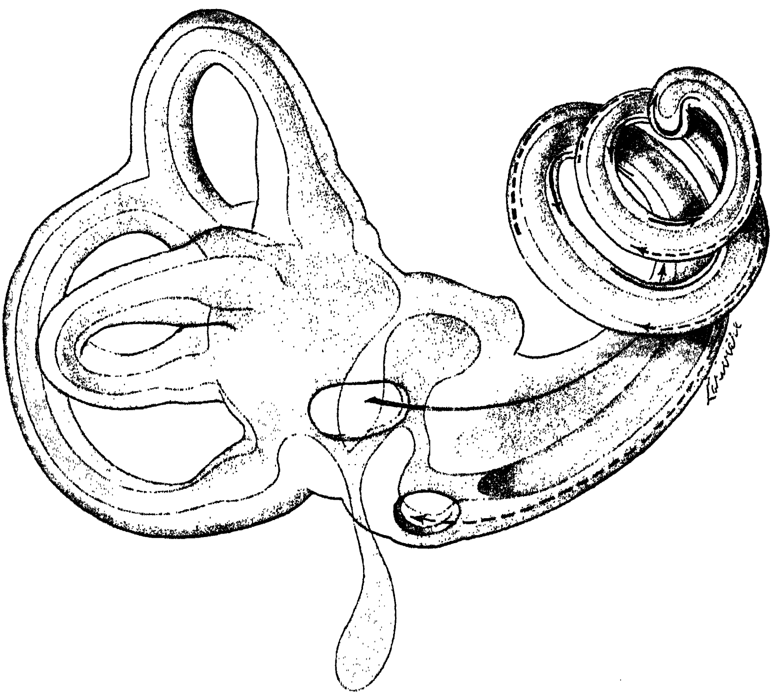
Structure (fig. 1061).—The walls of the utricle, saccule and semicircular ducts consist of three layers. The *outer layer* is composed of ordinary fibrous tissue containing blood-

* J. K. Milne Dickie, *Journal of Laryngology, Rhinology and Otology*, vol. xxxv.

† Loc. cit.

vessels and some pigment-cells. The *middle layer*, thicker and more transparent, is named the *tunica propria*, and presents on its internal surface, especially in the semicircular ducts (fig. 1061), numerous papilliform projections, which, on the addition of acetic acid, exhibit an appearance of longitudinal fibrillation. The *inner layer* is formed of polygonal, nucleated, epithelial cells. In the maculæ of the utricle and saccule (fig. 1062), and in the ampullary crests of the semicircular ducts, the middle coat is thickened and the epithelium is columnar, and consists of *supporting cells* and *hair-cells*. The supporting cells are fusiform, and their deep ends are attached to the tunica propria, while their free extremities are united to form a thin cuticle. The hair-cells are flask-shaped, and their deep, rounded ends do not reach the tunica propria, but lie between the supporting cells. The free end of the cell is surmounted by a long, tapering hair-like filament, which projects into the cavity. The filaments of the vestibular nerve, having pierced the tunica propria, lose their medullary sheaths, and their axis-cylinders split up into fine fibrils which end between the hair-cells.

FIG. 1060.—Scheme of the membranous labyrinth (*blue*) projected on to the osseous labyrinth.



The arrows commence at the fenestra vestibuli and continue up the scala vestibuli to the helicotrema, and then pass down the scala tympani to the fenestra cochleæ.

Two small rounded bodies termed *otoliths*, consisting of crystals of calcium carbonate, are suspended in the endolymph in contact with the free ends of the hairs projecting from the maculæ.

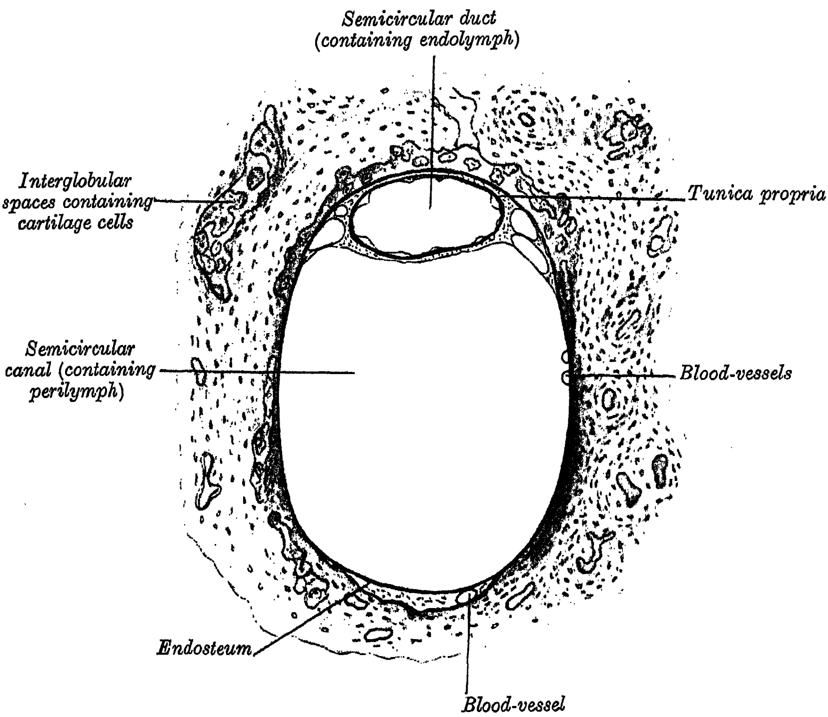
A ridge, named the *crista quarta*, projects into the posterior end of the lateral duct; nerves have been traced to this crest, which is present in most mammals but exists only in a rudimentary condition in the higher vertebrates.

The duct of the cochlea consists of a spirally arranged tube within the bony canal of the cochlea and lying along its outer wall.

As already stated (p. 1206) the osseous spiral lamina extends only part of the distance between the modiolus and the outer wall of the cochlea, while the *basilar membrane* stretches from the free edge of the lamina to the outer wall of the cochlea, and completes the roof of the scala tympani. A second and more delicate membrane, termed the *vestibular membrane*, extends from the thickened periosteum covering the osseous spiral lamina to the outer wall of the cochlea, where it is attached at some distance above the outer edge of the basilar membrane. A canal is thus shut off between the scala tympani below and the scala vestibuli above; this is the *duct of the cochlea* (figs. 1063, 1064). It is triangular on transverse section, its roof being formed by the vestibular membrane, its outer wall by the periosteum lining the bony canal, and its floor by the basilar

membrane and the outer part of the osseous spiral lamina. The upper extremity of the duct of the cochlea is closed, and is named the *lagæna* ; it is attached to the cupola. The lower end turns medially, and narrows into the *canalis reuniens*, through which it communicates with the saccule (fig. 1058). The spiral organ is situated on the basilar membrane. The vestibular membrane is thin

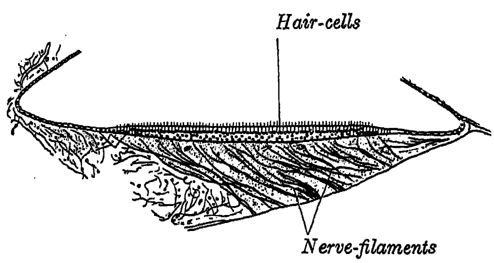
FIG. 1061.—A transverse section through the right posterior semicircular canal and duct of an adult man. ×51. (J. K. Milne Dickie.)



and homogeneous, and is covered on its two surfaces by a layer of flattened epithelium. The periosteum forming the outer wall of the duct of the cochlea is greatly thickened and altered in character. It projects inwards, inferiorly, as a triangular prominence, termed the *crista basilaris*, to which the outer edge of the basilar membrane is fixed ; immediately above this there is a concavity (the *sulcus spiralis externus*), above which the periosteum contains numerous blood-vessels, and is termed the *stria vascularis* (fig. 1064).

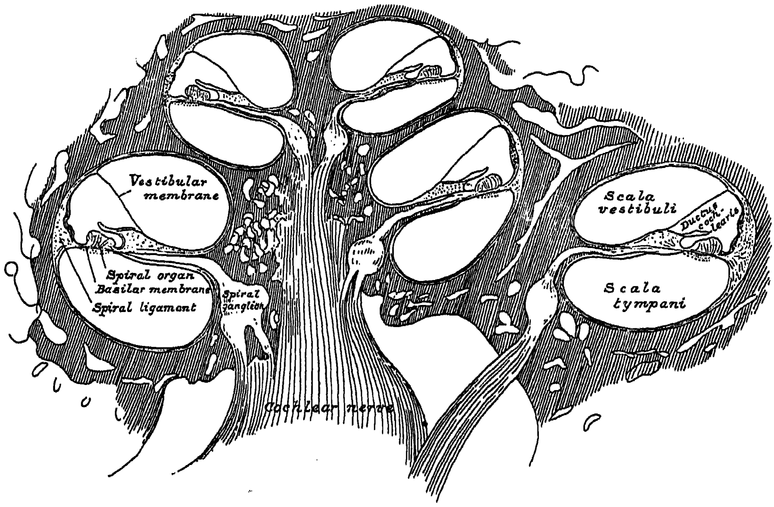
The osseous spiral lamina consists of two plates of bone, and between these are the canals for the transmission of the filaments of the auditory nerve. On the upper plate of that part of the lamina which is contained within the duct of the cochlea the periosteum is thickened to form the *limbus laminæ spiralis* (fig. 1065) ; this ends externally in a concavity (the *sulcus spiralis internus*), which presents, on section, the form of the letter C ; the upper part formed by the overhanging edge of the limbus, is named the *vestibular lip* ; the lower part, prolonged and tapering, is called the *tympanic lip*, and is perforated by numerous foramina for the passage of the branches of the cochlear nerve. The upper surface of the vestibular lip

FIG. 1062.—A transverse section of the macula. (Retzius.)



is intersected at right angles by a number of furrows, separated by numerous elevations; these present the appearance of teeth on the free surface and margin of the lip, and were named by Huschke the *auditory teeth* (fig. 1065). The limbus is covered by a layer of what appears to be squamous epithelium, but only the cells covering the teeth are flattened, those in the furrows being

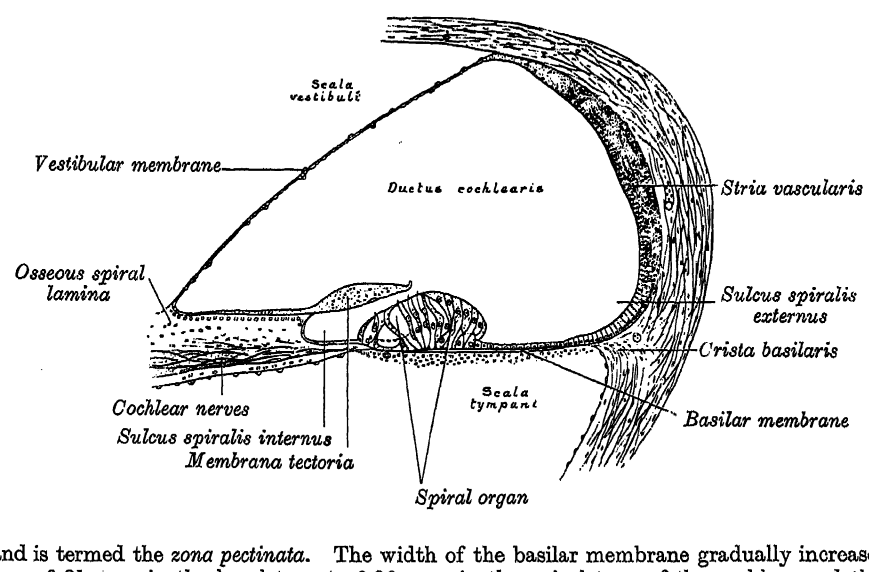
FIG. 1063.—A longitudinal section through the cochlea. Diagrammatic.



columnar, and occupying the intervals between the elevations. This epithelium is continuous on the one hand with that lining the sulcus spiralis internus, and on the other with that covering the under surface of the vestibular membrane.

The basilar membrane.—The basilar membrane (fig. 1066) stretches from the tympanic lip of the osseous spiral lamina to the crista basilaris. Its inner part is thin, and is named the *zona arcuata*; it supports the spiral organ; the outer part is thicker and striated,

FIG. 1064.—A transverse section through the middle coil of the ductus cochlearis. (Retzius.)

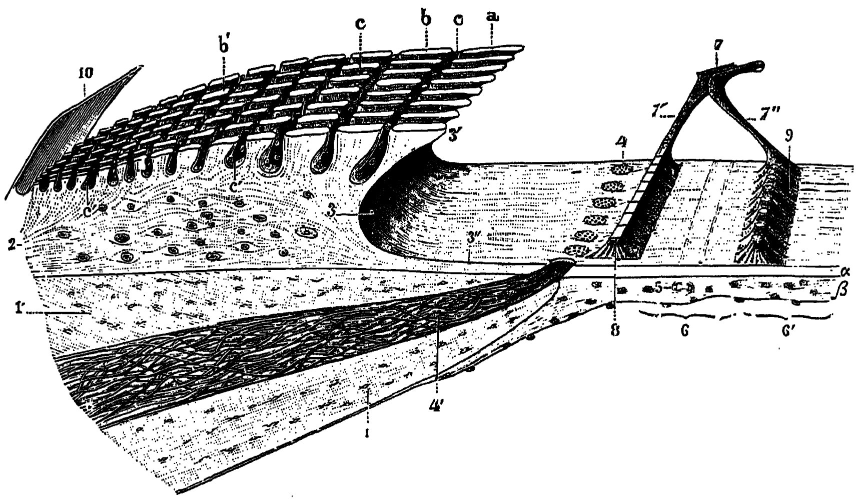


and is termed the *zona pectinata*. The width of the basilar membrane gradually increases from 0·21 mm. in the basal turn to 0·36 mm. in the apical turn of the cochlea, and this increase is accompanied by a corresponding narrowing of the osseous spiral lamina, and a

decrease in the thickness of the crista basilaris. The under surface of the membrane is covered by a layer of vascular connective tissue; one of the vessels in this tissue is somewhat larger than the rest, and is named the *vas spirale*; it lies below Corti's tunnel.

The spiral organ (figs. 1064, 1066) is composed of a series of epithelial structures placed upon the zona arcuata or inner part of the basilar membrane. The more central of these structures are two rows of rod-like bodies (the *inner and outer rods of Corti*). The bases or *foot-plates* of the rods are expanded, and rest on the basilar membrane, those of the inner row at some distance from those of the outer; the two rows incline towards each other and, coming into contact above, enclose between them and the basilar membrane the *tunnel of Corti* (fig. 1067), which is triangular in cross section. On the medial side of the inner rods there is a single row of hair-cells, and on the lateral side of the outer rods, three or four rows of hair-cells, together with certain supporting cells termed the cells of Deiters and of Hensen. The free ends of the outer hair-cells occupy a series of apertures in a

FIG. 1065.—The limbus laminæ spiralis and the basilar membrane. Schematic. (Testut.)



1, 1'. Upper and lower lamellæ of the lamina spiralis ossea. 2. Limbus laminæ spiralis, with *a*, the auditory teeth of the first row; *b*, *b'*, the teeth of the other rows; *c*, *c'*, the grooves between the auditory teeth and the cells which are lodged in them. 3. Sulcus spiralis internus, with 3', its labium vestibulare, and 3", its labium tympanicum. 4. Foramina nervosa, giving passage to the nerves from the spiral ganglion. 5. Vas spirale. 6. Zona arcuata, and 6', zona pectinata of the basilar membrane, with *α*, its hyaline layer, *β*, its connective tissue layer. 7. Summit of the tunnel of Corti, with 7', its inner rod, and 7", its outer rod. 8. Bases of the inner rods, from which the cells are removed. 9. Bases of the outer rods. 10. Part of the vestibular membrane.

net-like membrane, termed the *reticular lamina*, and the entire organ is covered by the *tectorial membrane*.

Rods of Corti (fig. 1067).—Each of these consists of a base or foot-plate, an elongated part or body, and an upper end or head; the body of each rod is finely striated, but in the head there is an oval non-striated portion which stains deeply with carmine. Nucleated cells, which partly envelop the rods and extend on to the floor of Corti's tunnel, occupy the angles between the rods and the basilar membrane; these may be looked upon as the undifferentiated parts of the cells from which the rods have been formed.

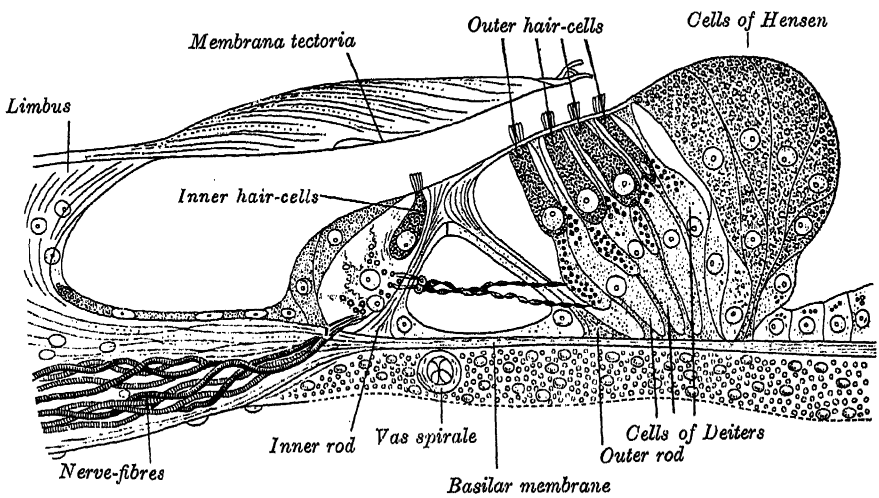
The *inner rods* number nearly 6000, and their bases rest on the basilar membrane close to the tympanic lip of the sulcus spiralis internus. The shaft or body of each is sinuously curved and forms an angle of about 60° with the basilar membrane. The head resembles the proximal end of the ulna, and presents a deep concavity which accommodates a convexity on the head of the outer rod. The head-plate, or portion overhanging the concavity, overlaps the head-plate of the outer rod.

The *outer rods*, nearly 4000 in number, are longer and more obliquely set than the inner, forming with the basilar membrane an angle of about 40°. Their heads are convex internally; they fit into the concavities on the heads of the inner rods, and are continued outwards as thin flattened plates, termed *phalangeal processes*, which unite with the phalangeal processes of Deiters' cells to form the reticular membrane.

The distances between the bases of the inner and outer rods increase from the base to the apex of the cochlea, while the angles between the rods and the basilar membrane diminish.

Hair-cells.—The hair-cells are short columnar cells; their free ends are on a level with the heads of the rods of Corti, and each is surmounted by about twenty hair-like processes arranged in the form of a crescent with its concavity directed inwards. The deep ends of the cells reach about halfway along the rods of Corti, and each contains a large nucleus; the terminal filaments of the cochlear nerve are in contact with the deep ends of the hair-cells. The *inner* hair-cells, about 3500 in number, are arranged in a single row on the inner (axial) side of the inner rods, and, their diameters being greater than those of the rods, each is supported by more than one rod. The free ends of the inner hair-cells are encircled by a cuticular membrane which is fixed to the heads of the inner rods. Adjoining the inner hair-cells there are one or two rows of columnar supporting cells, which, in turn, are continuous with the cubical cells lining the sulcus spiralis internus. The *outer* hair-cells number about 12,000 and are nearly twice as long as the inner. In the basal coil of the cochlea they are arranged in three regular rows; in the apical coil, in four somewhat irregular rows.

FIG. 1066.—A transverse section through the spiral organ. Magnified. (G. Retzius.)



Rows of supporting cells, called the *cells of Deiters* (fig. 1066), are placed between the rows of the outer hair-cells; their expanded bases are planted on the basilar membrane, while the opposite end of each presents a clubbed extremity or *phalangeal process.* Immediately to the outer side of Deiters' cells there are five or six rows of columnar cells, named the *supporting cells of Hensen* (fig. 1066). Near the lagæna these cells contain fat globules which decrease in number and size as the duct of the cochlea is traced towards the basal coil. It has been suggested * that these globules provide a graduated loading mechanism, which tunes the region of the lagæna to low tones.

The *reticular lamina* (fig. 1067) is a delicate framework perforated by circular holes which are occupied by the free ends of the outer hair-cells. It extends from the heads of the outer rods of Corti to the external row of the outer hair-cells, and is formed by several rows of minute fiddle-shaped cuticular structures, called *phalanges,* between which are circular apertures containing the free ends of the hair-cells. The innermost row of phalanges consists of the phalangeal processes of the outer rods of Corti; the outer rows are formed by the modified free ends of Deiters' cells.

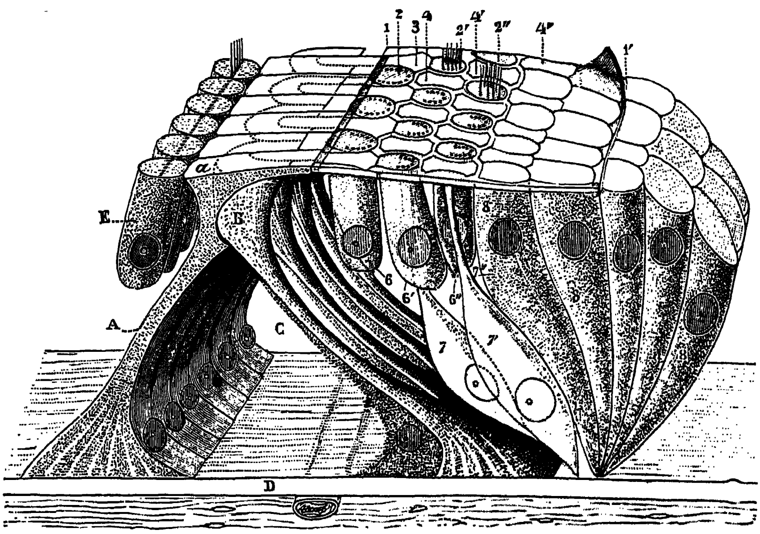
The *membrana tectoria* (fig. 1066) overlies the sulcus spiralis internus and the spiral organ of Corti. It is wider and thicker in the apical than in the basal part of the cochlea. Its inner part is thin and is attached to the vestibular lip of the limbus laminæ spiralis, the attachment reaching as far as the vestibular membrane. The outer part is thick and padlike, the thickness being greatest over, or slightly to the inner side of, the upper ends of the rods of Corti. Retzius described the outer edge as being attached to the outer row of Deiters' cells, while others maintain that it forms a ragged or frayed margin. Hardesty, † who has examined the membrane in the pig, states that this edge is free and bluntly rounded, but finely and irregularly scalloped. The hairs of the hair-cells project into the under surface of the membrane, and on this surface opposite the interval between the inner and outer rows of hair-cells there is a band, named *Hensen's stripe.*

* C. S. Hallpike, *Journal of Physiology,* vol. lxxiii.

† Irving Hardesty, *American Journal of Anatomy,* vol. viii.

Hardesty has shown that the membrana tectoria "consists of multitudes of delicate fibrils imbedded in a transparent matrix of a soft, collagenous, semi-solid character with marked adhesiveness." The prevailing course of the fibres is obliquely transverse, slanting from the vestibular lip towards the apex of the cochlea. The fibres pass in curves from the vestibular lip and upper surface of the membrane to its under surface, where by their interlacement they produce the appearance known as Hensen's stripe. He also described

FIG. 1067.—The reticular lamina and subjacent structures. Schematic. (Testut.)



A. Inner rod of Corti, with *a*, its head. B. Outer rod (in yellow). C. Tunnel of Corti. D. Basilar membrane. E. Inner hair-cells. 1, 1'. Internal and external borders of the reticular lamina. 2, 2', 2". The three rows of circular holes (in blue). 3. First row of phalanges (in yellow). 4, 4', 4". Second, third, and fourth rows of phalanges (in red). 6, 6', 6". The three rows of outer hair-cells (in blue). 7, 7', 7". Cells of Deiters. 8. Cells of Hensen and Claudius.

a thin, exceedingly delicate *accessory tectorial membrane*, lying along the under surface of the outer zone of the main membrane, and lightly attached to the latter by its outer edge.

The **auditory nerve**, or nerve of hearing, divides near the bottom of the internal auditory meatus into an anterior or cochlear, and a posterior or vestibular portion. The deep connexions of these nerves are described on pp. 1064 to 1067.

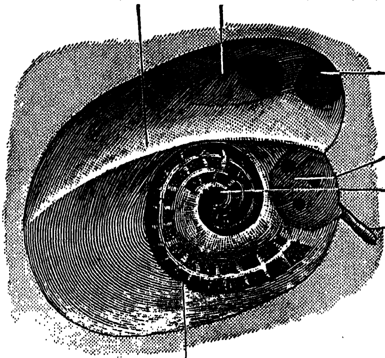
The *vestibular nerve* supplies the utricle, the saccule and the ampullæ of the semicircular ducts. The *vestibular ganglion*, from the bipolar nerve-cells of which the fibres of the nerve take origin, is situated on the trunk of the nerve within the internal auditory meatus. On the distal side of the ganglion the nerve splits into a superior, an inferior and a posterior branch.* The filaments of the *superior branch* are transmitted through the foramina in the superior vestibular area, and end in the macula of the utricle and in the ampullary crests of the superior and lateral semicircular ducts; those of the *inferior branch* traverse the foramina in the inferior vestibular area, and end in the macula of the saccule. The *posterior branch* runs through the foramen singulare at the postero-inferior part of the bottom of the meatus and divides into filaments for the supply of the ampullary crest of the posterior semicircular duct (fig. 1068).

The *cochlear nerve*, the nerve of hearing, divides into numerous filaments at the base of the modiolus; those for the basal and middle coils pass through the foramina in the tractus spiralis foraminosus, those for the apical coil through the central canal, and the nerves bend outwards and pass between the lamellæ

* The nerve sometimes splits on the proximal side of the ganglion, which is then divided into three parts, one on each branch of the nerve. When this occurs the ganglion of the posterior division is placed in the foramen singulare.

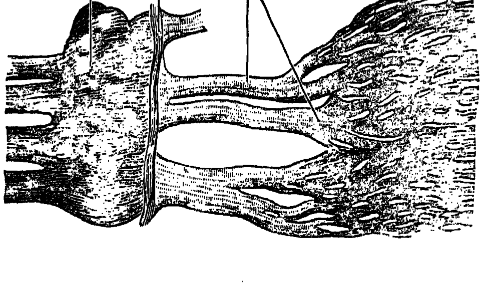
of the osseous spiral lamina. The *spiral ganglion* (fig. 1069), consisting of bipolar nerve-cells from which the fibres of the nerve take origin, occupies the spiral canal of the modiolus. Reaching the outer edge of the osseous spiral lamina, the nerve-fibres pass through the foramina in the tympanic lip; some end by arborising around the deep ends of the inner hair-cells, while

FIG. 1068.—A diagrammatic view of the lateral end of the right internal meatus. (Testut.)



others pass between the rods of Corti and across the tunnel of Corti, and end in a similar manner in relation to the outer hair-cells. The hair-cells in the basal and middle coils are more richly supplied with nerves than those in the apical coil. The cochlear nerve gives off a vestibular branch to supply the vestibular end of the duct of the cochlea; the filaments of this branch traverse the foramina in the cochlear recess (p. 1204).

FIG. 1069.—Part of the cochlear division of the auditory nerve. Highly magnified. (Henle.)



Vessels.—The *arteries of the labyrinth* are (1) the internal auditory artery, which may arise from the basilar artery, but is more often derived from the anterior inferior cerebellar artery, and (2) the stylomastoid branch of the posterior auricular artery. The internal auditory artery divides at the bottom of the internal auditory meatus into two branches: cochlear and vestibular. The cochlear branch subdivides into twelve or fourteen twigs, which traverse the canals in the modiolus, and are distributed, in the form of a capillary network, in the lamina spiralis and basilar membrane. The vestibular branches are distributed to the utricle, saccule and semicircular ducts.

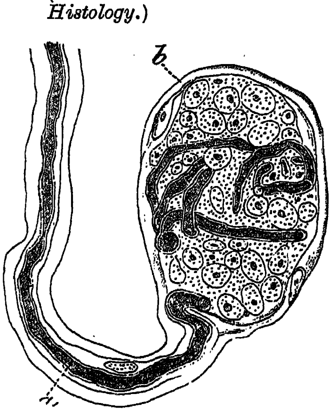
The *veins* of the vestibule and semicircular canals accompany the arteries, and, receiving the veins of the cochlea at the base of the modiolus, unite to form the internal auditory

vein, which ends in the posterior part of the superior petrosal sinus or in the transverse sinus. A small vein, from the basal turn of the cochlea, traverses the aqueduct of the cochlea and joins the internal jugular vein.

THE PERIPHERAL TERMINATIONS OF THE NERVES OF GENERAL SENSATIONS

The peripheral terminations of the nerves associated with general sensations (i.e. the muscular sense and the senses of touch, heat, cold, pain and pressure) are widely distributed throughout the body. These nerves may end (*a*) as *free fibrils* amongst the tissue elements, or (*b*) in *special end-organs* where the terminal nerve-filaments are enclosed in capsules.

FIG. 1070.—A bulbous corpuscle. (From Klein's *Elements of Histology*.)



a. Medullated nerve-fibre. *b*. Capsule.

Free nerve-endings occur chiefly in the epidermis and in the epithelium covering certain mucous membranes; they occur in the stratified squamous epithelium of the cornea, in the root-sheaths and papillæ of the hairs, and around the bodies of the sudoriferous glands.

When the nerve-fibre approaches its termination, the medullary sheath suddenly disappears, leaving the axis-cylinder surrounded by the neurolemma. After a time the fibre loses its neurolemma, and consists only of an axis-cylinder, which can be seen, in preparations stained with gold chloride, to be made up of fine varicose fibrillæ. Finally, the axis-cylinder breaks up into its constituent fibrillæ, which often present regular varicosities, and anastomosing with one another, end in small knobs or discs between the epithelial cells.

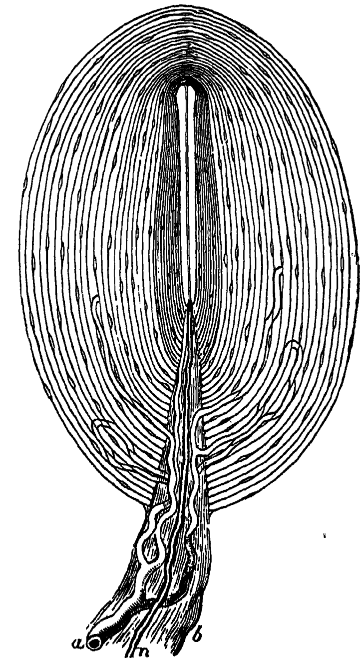
The **special end-organs** exhibit great variety in size and shape, but have one feature in common, viz. the terminal fibrils of the nerve are enveloped by a capsule. The bulbous, lamellated and oval corpuscles are included in this group, together with the neurotendinous and neuromuscular spindles.

The **bulbous corpuscles** (fig. 1070) are minute cylindrical or oval bodies, consisting of a capsule of connective tissue enveloping a soft semi-fluid core in which the axis-cylinder terminates, either in a bulbous extremity or in a coiled-up plexiform mass. End-bulbs are found in the conjunctiva of the eye, (where they are spheroidal in shape in man, but cylindrical in most other animals), in the mucous membrane of the lips and tongue, and in the epineurium of nerve-trunks. They are also found in the penis and clitoris, and have there received the name of *genital corpuscles*; in these situations they have a mulberry-like appearance, being constricted by connective tissue septa into from two to six knob-like masses. In the synovial strata of certain joints (e.g. those of the fingers), rounded or oval end-bulbs occur, and are designated *articular end-bulbs*.

The *lamellated corpuscles* (fig. 1071) are found in the subcutaneous tissue on the nerves of the palm of the hand and sole of the foot, and in the genital organs of both sexes; they also occur on the nerves of the joints, and in some other situations, as in the mesentery and pancreas of the cat and along the tibia of the rabbit. Each of these corpuscles is attached to, and encloses the termination of, a single nerve-fibre. The corpuscle (which is visible to the naked eye and can be most easily demonstrated in the mesentery of a cat) consists of a number of concentric lamellæ or capsules arranged around a central space, in which the nerve-fibre is contained. Each lamella is composed of bundles of fine connective tissue-fibres, and is lined on its inner surface by a single layer of flattened cells. The central space is elongated or cylindrical in shape, and

filled with a transparent core, in the middle of which the naked axis-cylinder traverses the space to near its distal extremity, where it ends in one or more small knobs. Todd and Bowman have described minute arteries as entering by the sides of the nerves and forming capillary loops in the intercapsular spaces, and even penetrating into the central space.

FIG. 1071.—A lamellated corpuscle, with its system of capsules and its central cavity.



a. Arterial twig, ending in capillaries, which form loops in some of the intercapsular spaces; one penetrates to the central capsule. *b.* The fibrous tissue of the stalk. *n.* Nerve-fibre advancing to the central capsule, there losing its medullary sheath, and passing along the core to the opposite end, where it terminates in a tuberculated enlargement.

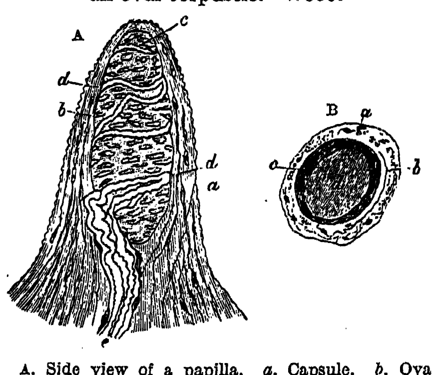
Other corpuscles are found in the subcutaneous tissue of the pulp of the fingers. They differ from lamellated corpuscles in that their capsules are thinner, their contained cores thicker, and in the latter the axis-cylinders ramify more extensively and end in flat expansions.

The *oval corpuscles* (fig. 1072) are oval-shaped bodies which occur in the papillæ of the corium of the hand and foot, the front of the forearm, the skin of the lips, the mucous membrane of the tip of the tongue, the palpebral conjunctiva and the skin of the nipple. The long axis of each corpuscle is placed at right angles to the skin or mucous surface. Each is enveloped by a connective tissue capsule, which sends membranous septa into the interior. The axis-cylinder passes through the capsule and, after making several spiral turns round the body of the corpuscle, ends in small globular or pear-shaped enlargements.

Ruffini described a special variety of nerve-ending in the subcutaneous tissue of the human finger (fig. 1073), and mostly situated at the junction of the corium with the subcutaneous tissue. They are oval in shape, and consist of strong connective tissue sheaths; inside these the nerve-fibres divide into numerous branches, which show varicosities and end in small free knobs.

The *neurotendinous spindles* are chiefly found near the junctions of tendons with muscles. Each is enclosed in a capsule which contains a number of enlarged tendon-fasciculi (*intrafusal fasciculi*). One or more nerve-fibres perforate the side of the capsule and lose their medullary sheaths; the axis-cylinders subdivide and end between the tendon-fibres in irregular discs or varicosities (fig. 1074).

FIG. 1072.—A papilla of the hand, containing an oval corpuscle. × 350.

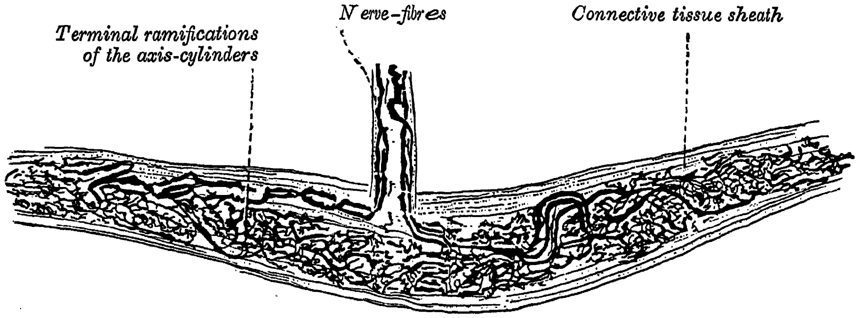


A. Side view of a papilla. *a.* Capsule. *b.* Oval corpuscle. *c.* Small nerve of the papilla, with neurolemma. *d.* Its two nerve-fibres running with spiral coils round the oval corpuscle. *e.* Apparent termination of one of these fibres. B. Transverse section of a tactile papilla. *a.* Capsule. *b.* Nerve-fibre. *c.* Outer layer of the oval corpuscle, with nuclei. *d.* Clear internal substance.

The *neuromuscular spindles* are present in the majority of voluntary muscles, and consist of small bundles of peculiar muscular fibres (*intrafusal fibres*), embryonic in type, invested by capsules, within which nerve-fibres, experimentally shown to be sensory, terminate. These neuromuscular spindles vary in length from 0·8 mm. to 5 mm. and have a fusiform appearance. The large medullated nerve-fibres passing to the end-organ are from one to three or four in number; entering the fibrous capsule, they

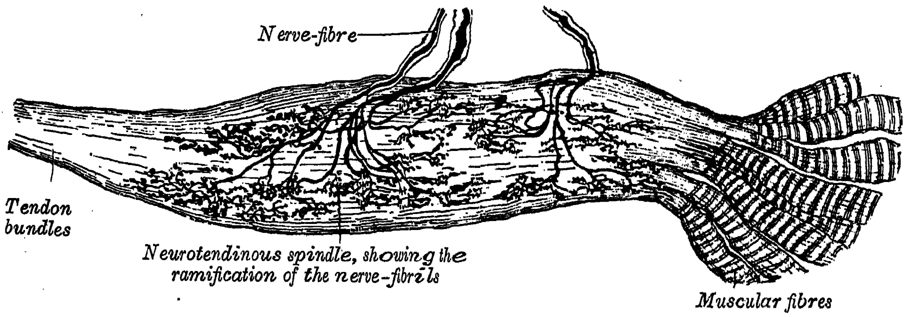
divide several times, and, losing their medullary sheaths, ultimately end in naked axis-cylinders encircling the intrafusal fibres by flattened expansions,

FIG. 1073.—A nerve-ending of Ruffini.



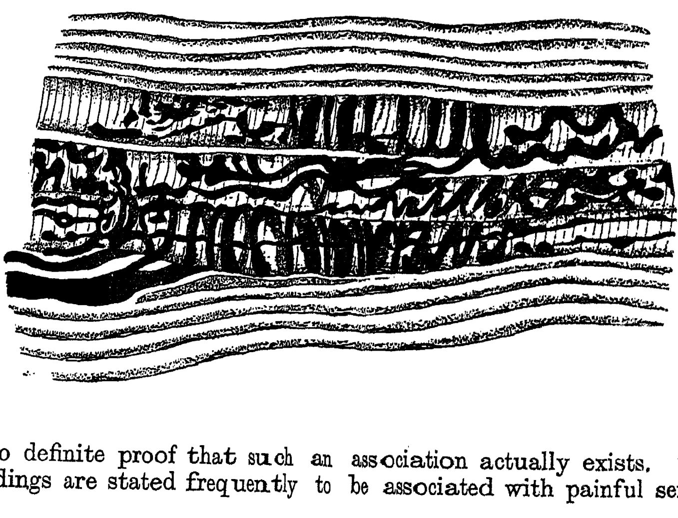
or irregular ovoid or rounded discs (fig. 1075). Neuromuscular spindles have not yet been demonstrated in the muscles of the tongue, and only a few exist in the ocular muscles.

FIG. 1074.—A neurotendinous spindle from the human tendo calcaneus. (After Ciaccio.)



The different ways in which sensory nerve-fibres terminate are strongly suggestive of their association with different types of sensibility, but there is

FIG. 1075.—The middle third of a terminal plaque in the muscle-spindle of an adult cat. (After Ruffini.)



as yet no definite proof that such an association actually exists. The free nerve-endings are stated frequently to be associated with painful sensibility,

but Waterston * has shown that, if they are to be regarded as associated with any one particular type of sensibility, they must be tactile in function. The subject has recently been investigated further by Woollard,† whose observations indicate that a nervous network is formed in association with the fine fibres which form subepidermal endings associated with pain, and that the intra-epidermal endings are concerned with touch.

The end-bulbs, or corpuscles, would appear to be an insulating mechanism and it might be assumed that each responds to only one form of stimulation, but, although Adrian ‡ has shown that the lamellated corpuscles respond to pressure but not to changes of temperature, the available evidence is quite inconclusive.§

THE SKIN

The **skin** (fig. 1076) covers the body and protects the deeper tissues. It contains the peripheral endings of many of the sensory nerves, plays an important part in the regulation of the body temperature, and possesses limited excretory and absorbing powers. It consists principally of a layer of vascular connective tissue, named the *corium*, and an external covering of epithelium, termed the *epidermis*. On the surface of the former layer there are sensitive and vascular *papillæ* ; and within, or beneath it, there are certain organs with special functions : namely, the *sweat* and *sebaceous glands*, and the *hair-follicles*.

The **epidermis** is non-vascular, and consists of stratified epithelium (fig. 1077). It varies in thickness in different parts. In some situations, as in the palms of the hands and soles of the feet, it is thick, hard, and horny in texture. This may be in a measure due to the fact that these parts are exposed to intermittent pressure, but that this is not the only cause is proved by the fact that the condition exists to a very considerable extent at birth. The more superficial layers of cells form the *horny zone* (*zona corneum*), which may be separated by maceration from a deeper stratum, termed the *germinative zone* and consisting of several layers of variously shaped cells. The free surface of the epidermis is marked by a network of linear furrows of variable size, which divide the surface into a number of polygonal or lozenge-shaped areas. These furrows are conspicuous opposite the flexures of the joints, and correspond with the folds in the corium produced by the joint-movements. In other situations, as upon the back of the hand, they are faint, and intersect one another at various angles. Upon the palmar surfaces of the hands and fingers, and upon the soles of the feet, these lines are fine but very distinct, and are disposed in more or less parallel curves ; they depend upon the large size and peculiar arrangement of the papillæ upon which the epidermis is placed. In each individual the lines on the tips of the fingers and thumbs form distinct patterns unlike those of any other person. A method of determining the identity of a criminal is based on this fact, impressions (' finger-prints ') of these lines being made on paper covered with soot, or on white paper after first covering the fingers with ink. The deep surface of the epidermis is accurately moulded upon the papillary layer of the corium, the papillæ being covered by a basement-membrane ; as a result when the epidermis is removed by maceration, its under surface presents a number of pits or depressions corresponding with the papillæ, and ridges corresponding with the intervals between them. The papillary form of the corium prevents the epithelium from being stripped off the surface of the skin by shearing stresses.

Structure.—The epidermis consists of stratified epithelium, which is arranged in two zones, viz. : the germinative zone and the horny zone. The germinative zone, which is the deeper, consists of basal-cell and prickle-cell layers ; the horny zone consists of clear, granular and horny layers.

Germinative zone : (1) The *basal-cell layer* [stratum basale] consists of a layer of columnar cells with oblong nuclei. The cells are placed perpendicularly on a basement-membrane, to which they are attached by denticulated extremities.

* D. Waterston, *Brain*, vol. xlvi. 1923 ; and *Anatomy in the Living Model*, 1931.

† H. H. Woollard, *Journal of Anatomy*, vol. lxxi, Oct. 1936 and July, 1937.

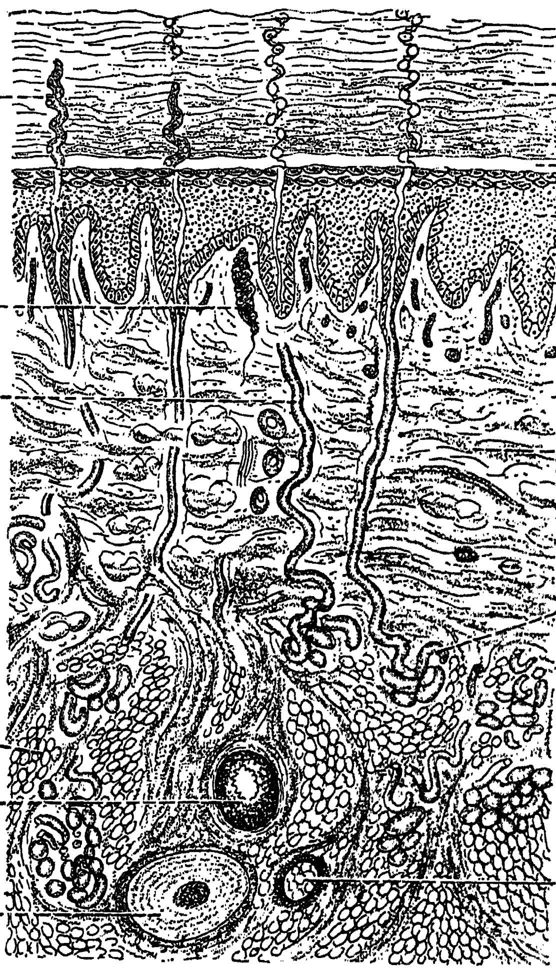
‡ E. D. Adrian, *The Basis of Sensation*, 1928.

§ J. S. B. Stopford, *Sensation and the Sensory Pathway*, 1930.

(2) The *prickle-cell layer* [stratum aculeatum] is composed of several layers of spherical or polyhedral cells, the contents of which are soft, opaque and granular. These cells are joined to one another by fine protoplasmic bridges. When the cells are isolated these bridges are broken and the surfaces of the cells are beset with numerous short thorn-like processes, which give the cells a characteristic appearance and have led to their being named *prickle-cells*. The cells contain numerous fine fibrils which can be stained by carmine or hæmatoxylin, and are continuous with those of neighbouring cells across the protoplasmic bridges. Between the bridges there are minute lymph-channels, in which lymph corpuscles or pigment-granules may be found.

Horny zone : (1) The *granular layer* [stratum granulosum] comprises two or three layers of fusiform cells which contain granules of *eleidin*, a substance readily stained by hæma-

FIG. 1076.—A section through the skin. Magnified. Diagrammatic.



toxylin or carmine, and probably an intermediate stage in the formation of keratin. They are supposed to be cells undergoing transformation from the protoplasmic cells of the stratum aculeatum to the horny cells of the superficial layers.

(2) The *clear layer* [stratum lucidum] appears in section as a homogeneous or dimly striated layer, composed of closely packed cells in which traces of flattened nuclei may be found, and in which the eleidin has been changed into a substance named *keratohyalin*.

(3) The *horny layer* [stratum corneum] consists of several layers of horny, epithelial cells, in which no nuclei are discernible. They are unaffected by acetic acid, and their protoplasm has been converted into a material known as *keratin*. According to Ranvier they contain granules of a substance which has the characteristics of beeswax.

The black colour of the skin in the negro and the tawny colour in some of the white races are due to the presence of pigment in the cells of the epidermis. This pigment is especially distinct in the prickle-cells, and is similar to that found in the cells of the pig-

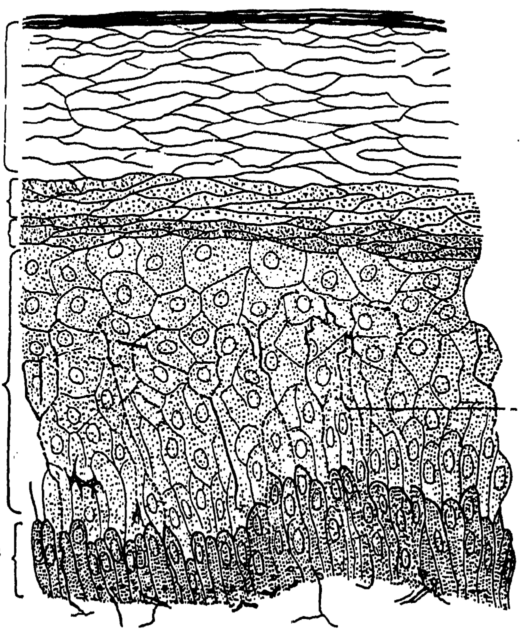
mented layer of the retina. As the cells approach the surface and desiccate, the pigment is partially lost.

The corium is tough, flexible and highly elastic. It is very thick in the palms of the hands and soles of the feet; thicker on the posterior than on the anterior aspect of the body, and on the lateral than on the medial sides of the limbs. It is exceedingly thin and delicate in the eyelids, scrotum, and penis.

Structure.—It consists of felted connective tissue, with a varying number of elastic fibres and numerous blood-vessels, lymphatic vessels and nerves. The connective tissue is arranged in two layers: a deeper or *reticular*, and a superficial or *papillary*. Unstriped muscular fibres are found in the superficial layers of the corium wherever hairs are present; they are also present in the subcutaneous areolar tissue of the scrotum, penis, labia majora and nipples. In the nipples the fibres are disposed in bands, closely reticulated and arranged in superimposed laminæ.

The *reticular layer* consists of strong interlacing bands, composed chiefly of white fibrous tissue, but containing some yellow elastic fibres, which vary in number in different parts;

FIG. 1077.—A section through the epidermis. (Ranvier.)



the connective tissue corpuscles are often to be found flattened against the bundles of white fibrous tissue. Towards the attached surface the fasciculi are coarse, and the large intervals left by their interlacement are occupied by adipose tissue and sweat glands. Below the reticular layer is the subcutaneous areolar tissue, which, except in a few situations, contains fat.

The *papillary layer* consists of numerous highly sensitive and vascular eminences, termed the *papillæ*, which rise perpendicularly from its surface. The papillæ are minute conical projections, having round or blunted extremities, which may be divided into two or more parts, and are received into corresponding pits on the under surface of the cuticle. On the general surface of the body, and especially in parts endowed with slight sensibility, they are few in number and exceedingly minute; but in some situations, as upon the palmar surfaces of the hands and fingers, and upon the plantar surfaces of the feet and toes, they are large, closely aggregated together, and arranged in parallel curved lines, forming the elevated ridges seen on the free surface of the epidermis. Each ridge contains two rows of papillæ, and between the rows the ducts of the sudoriferous glands pass outwards to open on the summits of the ridges. Each papilla consists of very small and closely interlacing bundles of finely fibrillated tissue, with a few elastic fibres; within this tissue there is a capillary loop, and in some papillæ, especially in the palms of the hands and the fingers, there are oval corpuscles.

The *arteries* supplying the skin form a network in the subcutaneous tissue, and from this

network branches are distributed to the sweat glands, the hair-follicles and the fat. Other branches unite in a plexus immediately beneath the corium, and from this plexus fine capillary vessels pass into the papillæ.

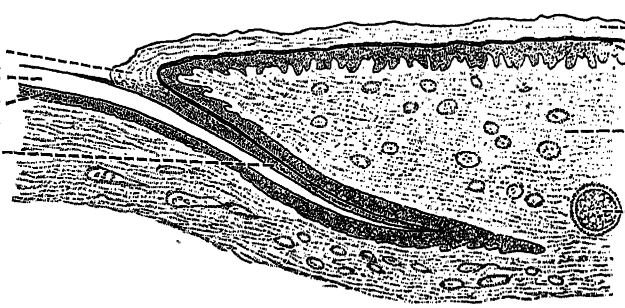
The *lymph vessels* of the skin form a superficial and a deep network, which communicate with each other and with the lymph vessels of the subcutaneous tissue by oblique branches.

The *nerves* of the skin terminate partly in the epidermis and partly in the corium; their different modes of ending are described on pp. 1216 to 1219.

The **appendages of the skin** are the nails, the hairs, and the sweat and sebaceous glands.

The **nails** (fig. 1078) are flattened, elastic structures of a horny texture, placed upon the distal parts of the dorsal surfaces of the fingers and toes. Each is implanted into a groove in the skin by a portion called the *root*; the exposed part is called the *body*, and the distal extremity, the *free border*. The greater part of each collateral border of the nail is overlapped by a fold of skin, named the *nail-wall*. The nail is firmly adherent to the corium, being accurately moulded upon its surface; the part of the corium beneath the nail is called the *nail-bed*. Under the greater part of the body of the nail the matrix is thick, and raised into a series of longitudinal ridges which are very vascular, and the colour is seen through the transparent tissue. Near the root of the

Fig. 1078.—A longitudinal section through the root of a nail.



nail the papillæ are smaller, less vascular, and have no regular arrangement, and here the tissue of the nail is more opaque; hence this portion is of a whiter colour, and is called the *lunula* on account of its shape.

As the epidermis passes forwards on the dorsal surface of the finger or toe it is attached to the surface of the nail a little in advance of its root; at the extremity of the digit it is connected with the under surface of the nail a little behind its free edge. The epidermis and the horny substance of the nail (also an epidermic structure) are thus directly continuous with each other. The superficial, horny part of the nail consists of a greatly thickened stratum lucidum, the stratum corneum forming merely the thin cuticular fold (*eponychium*) which overlaps the lunula; the deeper part consists of the stratum aculeatum. The cells in contact with the papillæ of the nail-bed are columnar in form and arranged perpendicularly to the surface; the succeeding cells are round or polygonal, while the more superficial ones are thin and flat, and so closely packed as to make the limits of the cells very indistinct. The nails grow in length by the proliferation of the cells of the stratum aculeatum at the root of the nail, and in thickness from that part of the stratum aculeatum which underlies the lunula.

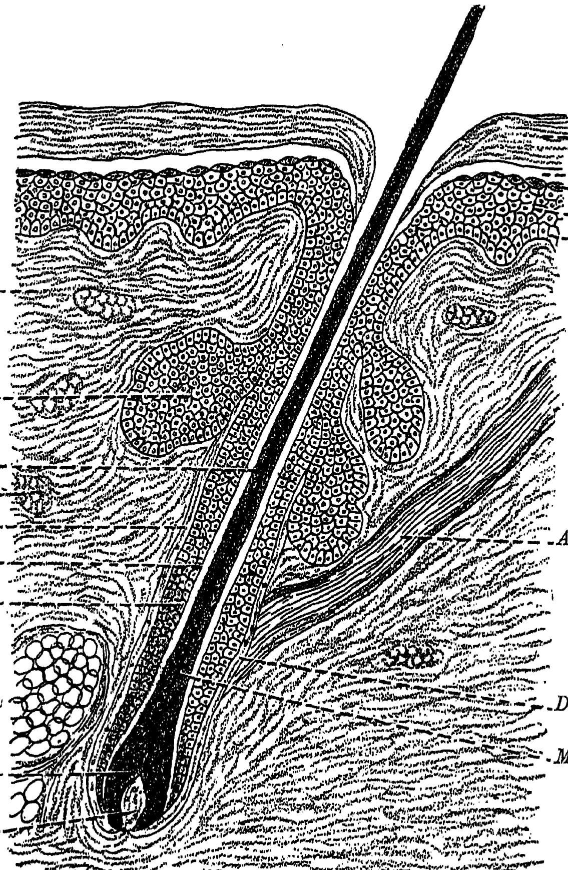
The **hairs** are found on nearly every part of the surface of the body, but are absent from the palms of the hands, the soles of the feet, the dorsal surfaces of the distal phalanges, the glans penis, the inner surface of the prepuce and the inner surfaces of the labia. They vary much in length, thickness, and colour in different parts of the body and in different races of mankind. In some parts, as in the skin of the eyelids, they are so short as not to project beyond the follicles containing them; in others, as upon the scalp, they are of considerable length; the eyelashes, the hairs of the pubic region, and the whiskers and beard are remarkable for their thickness. Straight hairs are stronger than curly hairs and

present on transverse section a cylindrical or oval outline: curly hairs, on the other hand, are flat.

A hair consists of a *root*, the part implanted in the skin; and a *shaft* [*scapus*], the portion projecting from the surface.

The *root of the hair* ends in an enlargement, named the *hair-bulb*, which is whiter in colour and softer in texture than the shaft, and is lodged in an involution of the epidermis and superficial portion of the corium, called the *hair-follicle* (fig. 1079). When the hair is of considerable length the follicle extends into the subcutaneous tissue. The hair-follicle commences on the surface of the skin with a funnel-shaped opening, and passes

Fig. 1079.—A section through the skin, showing the epidermis and corium, a hair in its follicle, the Arrector pili muscle, and sebaceous glands opening into the hair-follicle.



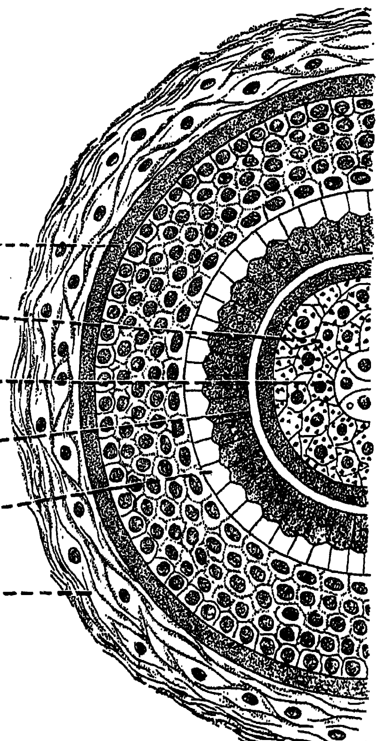
inwards in an oblique or curved direction—the latter in curly hairs—to become dilated at its deep extremity, where it corresponds with the hair-bulb. The ducts of one or more sebaceous glands open into the follicle near its free extremity. At the bottom of each hair-follicle there is a small conical, vascular eminence or papilla, similar in every respect to those found upon the surface of the skin; it is continuous with the dermic layer of the follicle, and is supplied with nerve-fibrils. The hair-follicle consists of two coats—an outer or dermic, and an inner or epidermic (fig. 1080).

The *outer coat* is formed mainly of fibrous tissue; it is continuous with the corium, is highly vascular, and is supplied by numerous, minute, nervous filaments. It consists of three layers (fig. 1080). The most internal is a hyaline basement-membrane, which is well marked in the larger hair-follicles but is not very distinct in the follicles of minute hairs; it is limited to the deeper part of the follicle. Outside this there is a compact layer of fibres and spindle-shaped cells, arranged circularly around the follicle; this layer extends from the bottom of the follicle to the openings of the ducts of the sebaceous glands. Externally there is a thick layer of connective tissue, arranged in longitudinal bundles,

forming a more open texture and corresponding with the reticular part of the corium; this contains the blood-vessels and nerves.

The *inner coat* is closely adherent to the root of the hair, and consists of two strata, named respectively the *outer* and *inner root-sheaths*; the outer root-sheath corresponds with the stratum aculeatum of the epidermis, and resembles it in the rounded form and soft character of its cells; at the bottom of the hair-follicle these cells become continuous with those of the root of the hair. The inner root-sheath consists of: (1) a delicate cuticle next the hair, composed of a single layer of imbricated scales with atrophied nuclei; (2) one or two layers of horny, flattened, nucleated cells, known as Huxley's layer; and (3) a single layer of cubical cells with clear, flattened nuclei, called *Henle's layer* (fig. 1080).

Fig. 1080.—A transverse section through one-half of a hair-follicle.



The *hair-bulb* is moulded over the papilla and composed of polyhedral, epithelial cells. As they pass upwards into the root of the hair these cells become elongated and spindle-shaped, except those in the centre, which remain polyhedral.

The *shaft of the hair* consists, from within outwards, of the medulla, the cortex and the cuticle. The *medulla* is usually absent from the fine hairs covering the surface of the body, and commonly from those of the head. When viewed by transmitted light it appears deeper in colour and more opaque than the cortex, but when viewed by reflected light it is white. It is composed of rows of polyhedral cells, with air-spaces between, and sometimes within, the cells. The *cortex* constitutes the chief part of the shaft; its cells are elongated and are united to form flattened, fusiform fibres, which contain pigment-granules in dark hair, and air in white hair. The *cuticle* consists of a single layer of flat scales which overlap one another from below upwards.

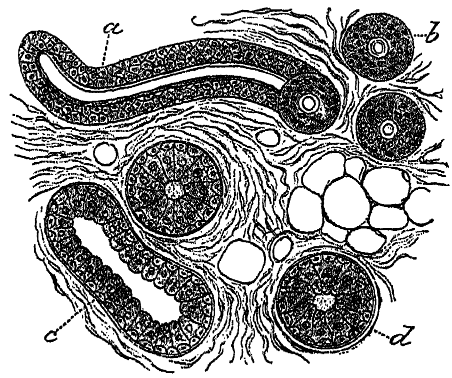
Minute bundles of involuntary muscular fibres, termed the *Arrectores pilorum* (fig. 1079), are connected with the hair-follicles. They arise from the superficial layer of the corium, and are inserted into the hair-follicle, below the entrance of the duct of the sebaceous gland. They are placed on the side towards which the hair slopes, and by their action diminish the obliquity of the follicle and elevate the hair.* The sebaceous gland is situated in the angle which the Arrector muscle forms with the superficial portion of the hair-follicle, and contraction of the muscle thus tends to squeeze the sebaceous secretion out from the duct of the gland.

The **sebaceous glands** (fig. 1079) are small, sacculated, glandular organs, lodged in the substance of the corium. They are found in most parts of the skin, but are especially abundant in the scalp and face; they are also very numerous around the apertures of the anus, nose, mouth and external ear, but are wanting in the palms of the hands and soles of the feet. Each gland consists of a single duct, more or less capacious, which emerges from a cluster of oval or flask-shaped alveoli, usually from two to five, but in some instances as many as twenty in number. Each alveolus is composed of a transparent basement-membrane, enclosing a number of epithelial cells. The outer or marginal cells are small and polyhedral, and are continuous with the cells lining the duct.

* Arthur Thomson suggested that the contraction of these muscles on follicles which contain weak, flat hairs will tend to produce a permanent curve in the follicle, and this curve will be impressed on the hair which is moulded within it so that the hair, on emerging through the skin, will be curled. Curved hair-follicles are characteristic of the scalp of the Bushman.

The remainder of the alveolus is filled with larger cells, containing fat, but in its centre the cells are broken up, leaving a cavity filled with their debris and a mass of fatty matter, which constitutes the *sebum cutaneum*. The ducts open most frequently into the hair-follicles, but occasionally upon the general surface, as in the labia minora and the free margins of the lips. On the nose and face the glands are of large size, distinctly lobulated, and often become much enlarged from the accumulation of pent-up secretion. The tarsal glands of the eyelids are elongated, sebaceous glands with numerous, lateral diverticula.

Fig. 1081.—The body of a sudoriferous gland cut in various directions. (From Klein and Noble Smith's *Atlas of Histology*.)



a. Longitudinal section through the proximal part of the coiled tube. *b*. Transverse section through the same. *c*. Longitudinal section through the distal part of the coiled tube. *d*. Transverse section through the same.

The sweat glands (figs. 1076, 1081) are found in almost every part of the skin, and are situated in small pits on the under surface of the corium, or, more frequently, in the subcutaneous tissue, surrounded by a quantity of adipose tissue. Each consists of a single tube, the deep part of which is rolled into an oval or spherical ball, named the *body* of the gland, while the superficial part, or *duct*, traverses the corium and cuticle and opens on the surface of the skin by a funnel-shaped aperture. In the superficial layers of the corium the duct is straight, but in the deeper layers it is convoluted or twisted; where the epidermis is thick, as in the palms of the hands and soles of the feet, the part of the duct which passes through it is spirally coiled. The size of the glands varies. They are especially large in those regions where the amount of perspiration is great, as in the axillæ, where they form a thin, mamillated layer of a reddish colour, which corresponds exactly with the situation of the hair in this region; they are large also in the groin. Their number varies. They are very plentiful on the palms of the hands, and on the soles of the feet, where the orifices of the ducts are exceedingly regular, and open on the curved ridges of the epidermis; they are least numerous in the neck and back. The tube, both in the body of the gland and in the duct, consists of two layers—an outer, of fine areolar tissue, and an inner, of epithelium (fig. 1081). The outer layer is thin and is continuous with the superficial stratum of the corium. In the body of the gland the epithelium consists of a single layer of cubical cells, between the deep ends of which and the basement-membrane there is a layer of longitudinally or obliquely arranged non-striped muscular fibres. The ducts are destitute of muscular fibres, and are composed of a basement-membrane lined by two or three layers of polyhedral cells; the lumen of the duct is coated by a thin cuticle. When the epidermis is carefully removed from the surface of the corium, the ducts may be drawn out in the form of short, thread-like processes on its under surface.

The ceruminous glands of the external auditory meatus are modified sweat glands.

SPLANCHNOLOGY

THE organs which constitute the respiratory, digestive and urogenital systems, and the ductless glands, are described under this heading.

THE RESPIRATORY SYSTEM

The respiratory system comprises the two lungs, which are the essential organs of the system, and a series of air-passages which conduct air to them. In addition the two pleural sacs, which are derived from the general cœlom and are inseparably associated with the lungs, are included under this heading.

The air-passages are the nasal cavity, the pharynx, the larynx, the trachea, the bronchi and their smaller subdivisions. Owing to the gaseous nature of their contents the air-passages must be kept constantly patent and their walls are therefore provided with a skeletal framework of bone or cartilage. In the nasal cavity, which is described on pp. 273 to 277, and the pharynx, which is described on pp. 1290 to 1298, the skeletal framework is osseous for the most part, but in the remaining passages it consists entirely of cartilage.

The Larynx

The **larynx**, which is the organ of the voice as well as an air-passage, is situated between the root of the tongue and the trachea, at the upper and anterior part of the neck. In this situation it projects forwards between the great vessels, and is covered anteriorly by the skin, the fasciæ, and the depressor muscles of the hyoid bone (fig. 1082). Above, it opens into the laryngeal part of the pharynx, of which it forms the anterior wall; below, it is continuous with the trachea. In the adult male it is situated opposite the third, fourth, fifth and sixth cervical vertebræ, but it occupies a somewhat higher position in the child and in the adult female. Symington states that in infants of between six and twelve months the tip of the epiglottis, or highest part of the larynx, is a little above the level of the cartilaginous disc between the odontoid process and the body of the axis. Its average measurements in the adult are as follows:

	In males.	In females.
Length	44 mm.	36 mm.
Transverse diameter	43 ,,	41 ,,
Anteroposterior diameter	36 ,,	26 ,,
Circumference	136 ,,	112 ,,

Until puberty the larynx of the male differs little in size from that of the female. In the female its increase at puberty is only small. In the male the increase is considerable; all the cartilages enlarge and the thyroid cartilage projects in the anterior median line of the neck, while the anteroposterior diameter is nearly doubled.

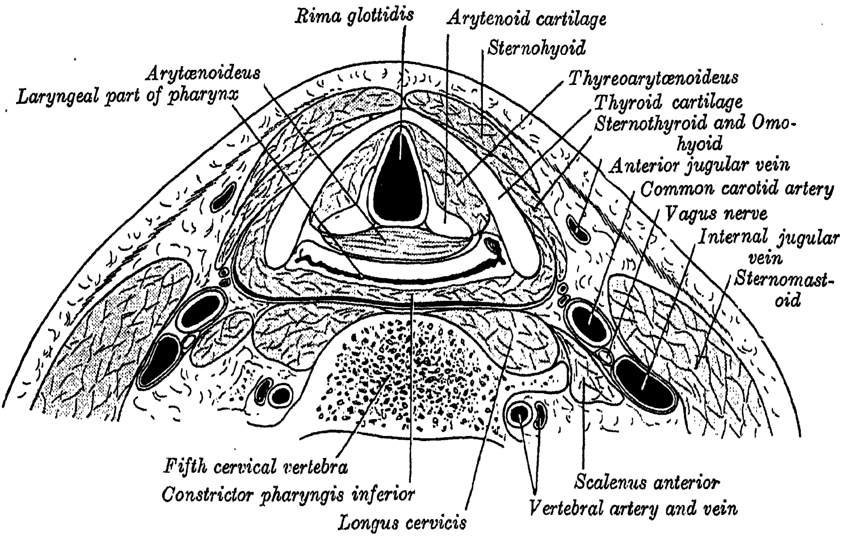
The skeletal framework of the larynx is formed of cartilages, which are connected by ligaments and membranes, and are moved by numerous muscles. It is lined with mucous membrane continuous above and behind with that of the pharynx and below with that of the trachea.

The **cartilages of the larynx** are nine in number, three single and three paired, viz.:

Thyroid.	Two Arytenoid.
Cricoid.	Two Corniculate.
Epiglottis.	Two Cuneiform.

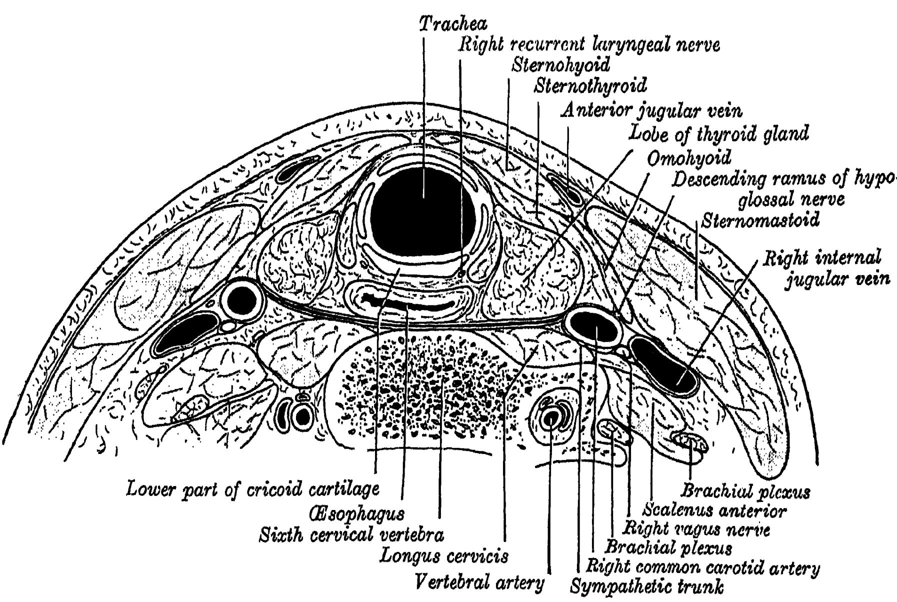
The **thyroid cartilage** (figs. 1082, 1084, 1085) is the largest cartilage of the larynx. It consists of two laminæ, the anterior borders of which are fused at an angle in the median plane, and form a subcutaneous projection named

FIG. 1082.—A section across the anterior part of the neck at the level of the vocal folds.



the *laryngeal prominence* (Adam's apple) (fig. 1082). This prominence is most distinct at its upper part, and is well marked in the male but scarcely visible in the female. Immediately above it the laminæ are separated by a V-shaped notch, termed the *thyroid notch.*

FIG. 1083.—A section across the anterior part of the neck at the level of the lower part of the lamina of the cricoid cartilage.



The *laminæ* are irregularly quadrilateral in shape, and their posterior angles are prolonged into processes termed the *superior* and *inferior horns.*

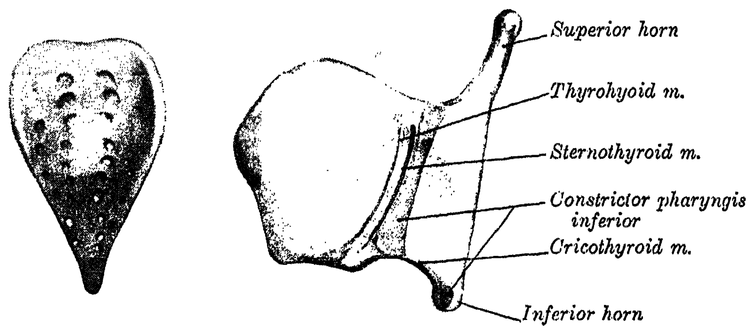
On the *outer surface* of each lamina an *oblique line* runs downwards and forwards from the superior thyroid tubercle, which is situated a little in front

of the root of the superior horn, to the inferior thyroid tubercle on the lower border of the lamina. This line gives insertion to the Sternothyroid, and origin to the Thyrohyoid and Constrictor pharyngis inferior. The *inner surface* is smooth: above and behind, it is slightly concave and covered with mucous membrane. In front, in the angle formed by the junction of the laminæ, the thyro-epiglottic ligament is attached, and on each side the vestibular (ventricular) and vocal ligaments, the Thyreoarytænoideus, Thyreoepiglotticus and Vocalis muscles gain attachment.

The *upper border* of each lamina is concave behind and convex in front; it gives attachment to the corresponding half of the thyrohyoid membrane. The *lower border* is concave behind, and nearly straight in front, the two parts being separated by the inferior thyroid tubercle. A small part of it in and near the median plane is connected to the cricoid cartilage by the cricothyroid ligament.

The *anterior* border is fused with that of the opposite lamina, forming with it an angle of about 90° in men, and about 120° in women. In men the greater projection of the laryngeal prominence, the greater length of the vocal fold and the resultant deeper pitch of the voice are all associated with the smaller size of the thyroid angle. The *posterior border*, thick and rounded, re-

FIG. 1084.—The epiglottis, posterior surface, and the left lamina of the thyroid cartilage, lateral surface.



ceives the insertions of fibres of the Stylopharyngeus and Palatopharyngeus (Pharyngopalatinus) muscles. It ends in the superior and inferior horns. The *superior horn*, long and narrow, is directed upwards, backwards and medially, and ends in a conical extremity, which gives attachment to the lateral thyrohyoid ligament. The *inferior horn*, short and thick, is directed downwards, with a slight inclination forwards and medially; on the medial surface of its lower end there is a small oval facet for articulation with the side of the cricoid cartilage.

During infancy a narrow, lozenge-shaped, flexible strip, named the *intrathyroid cartilage*, occupies the interval between the two laminæ anteriorly and is joined to them by connective tissue.

The **cricoid cartilage** (figs. 1086 to 1089) is smaller, but thicker and stronger than the thyroid cartilage. It is shaped like a signet-ring, and forms the lower parts of the anterior and lateral walls and most of the posterior wall of the larynx. It comprises a quadrate posterior lamina, and a narrow anterior arch.

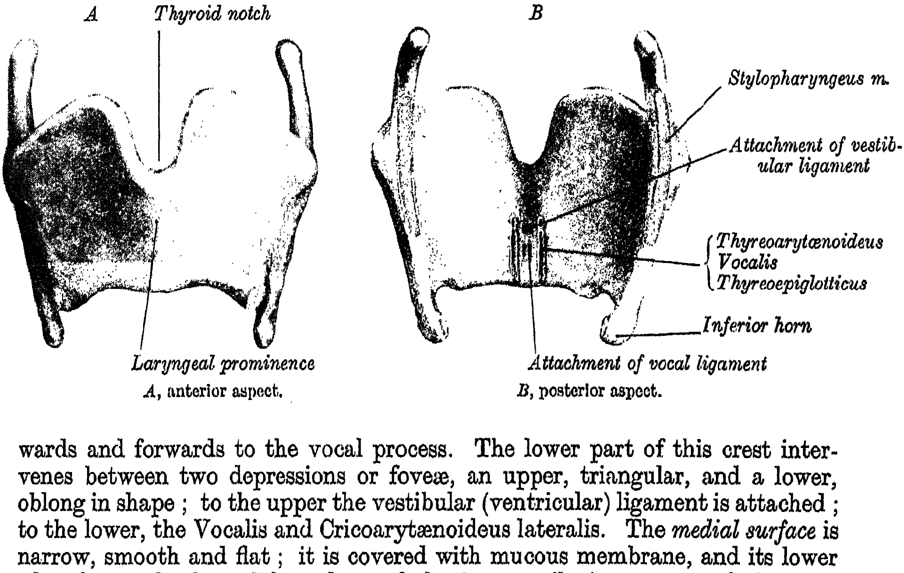
The *lamina* of the cricoid cartilage is deep and broad, and measures vertically from 2 cm. to 3 cm.; the posterior surface is marked by a median, vertical ridge, to the upper part of which the two fasciculi of the longitudinal fibres of the œsophagus are attached by a tendon (p. 1301); and on each side of the ridge there is a shallow depression for the origin of the Cricoarytænoideus posterior. The *arch* is narrow in front, measuring vertically from 5 mm. to 7 mm., but widens posteriorly as it approaches the lamina; on each side it affords attachment in front and at the side to the Cricothyroid muscle, and behind, to part of the Inferior constrictor of the pharynx. It can be felt easily in the living subject below the laryngeal prominence and separated from it by a slight depression which corresponds to the cricothyroid ligament. On each side, at the junction of the lamina with the arch, there is a prominent circular

facet, directed laterally and backwards, for articulation with the inferior horn of the thyroid cartilage. The *lower border* of the cricoid cartilage is horizontal, and connected to the highest ring of the trachea by the cricotracheal ligament. The *upper border* runs obliquely upwards and backwards, owing to the great depth of the lamina. It gives attachment, in front, to the cricothyroid ligament; at the sides, to the cricovocal membrane (conus elasticus) and the Cricoarytænoidei laterales; behind, it presents a median shallow notch, and on each side of this there is a smooth, oval, convex surface, directed upwards and laterally, for articulation with the base of the arytenoid cartilage. The *inner surface* of the cricoid cartilage is lined with mucous membrane.

The paired **arytenoid cartilages** (figs. 1086, 1088) are situated at the upper border of the lamina of the cricoid cartilage, at the back of the larynx. Each is pyramidal in form, and has three surfaces, a base and an apex.

The *posterior surface*, triangular, smooth and concave, is covered with the Arytænoideus transversus. The *anterolateral surface* is somewhat convex and rough. On it, near the apex of the cartilage, there is an elevation (*colliculus*) from which a crest (*crista arcuata*) curves at first backwards and then down-

Fig. 1085.—The thyroid cartilage.



A, anterior aspect. *B*, posterior aspect.

wards and forwards to the vocal process. The lower part of this crest intervenes between two depressions or foveæ, an upper, triangular, and a lower, oblong in shape; to the upper the vestibular (ventricular) ligament is attached; to the lower, the Vocalis and Cricoarytænoideus lateralis. The *medial surface* is narrow, smooth and flat; it is covered with mucous membrane, and its lower edge forms the lateral boundary of the intercartilaginous part of the rima glottidis. The *base* is concave, and presents a smooth surface for articulation with the upper border of the lamina of the cricoid cartilage. Its lateral angle or *muscular process*, rounded and prominent, projects backwards and laterally, and gives insertion to the Cricoarytænoideus posterior behind, and to the Cricoarytænoideus lateralis in front. Its anterior angle or *vocal process* is pointed; it projects horizontally forwards and gives attachment to the vocal ligament. The *apex* curves backwards and medially, and articulates with the *corniculate cartilage*.

The **corniculate cartilages** (figs. 1088, 1095) are two small conical nodules of yellow elastic cartilage which articulate with the summits of the arytenoid cartilages and serve to prolong them backwards and medially. They are situated in the posterior parts of the aryepiglottic folds of mucous membrane, and are sometimes fused with the arytenoid cartilages.

The **cuneiform cartilages** (fig. 1089) are two small, elongated pieces of yellow elastic cartilage, placed one in each aryepiglottic fold, where they give rise to whitish elevations on the surface of the mucous membrane, just in front of the corniculate cartilages.

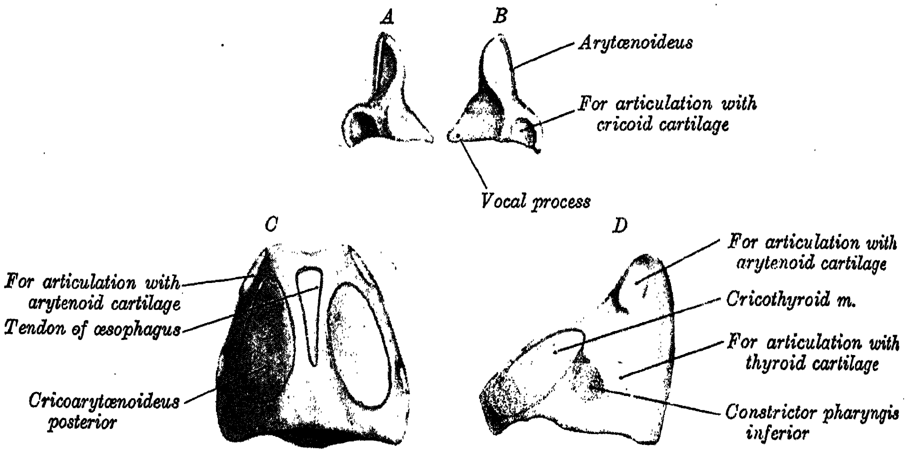
The cartilage of the **epiglottis** * (figs. 1085, 1088, 1089) is a thin, leaf-like lamella of yellow fibrocartilage, which projects obliquely upwards behind the

* The "Function of the Epiglottis" is discussed by V. E. Negus. *Journal of Anatomy*, vol. 62, 1927.

tongue and the body of the hyoid bone, and in front of the entrance to the larynx. The free extremity, broad and rounded, is directed upwards; the attached part or stem is long, narrow, and connected by an elastic ligament, named the *thyro-epiglottic ligament,* to the angle formed by the two laminæ of the thyroid cartilage, a short distance below the thyroid notch. The sides of the epiglottis are attached to the arytenoid cartilages by the aryepiglottic folds of mucous membrane (p. 1233).

The upper part of the *anterior surface* of the epiglottis is free, and covered with mucous membrane, which is reflected on to the pharyngeal part of the tongue and on to the lateral wall of the pharynx, forming a median *glosso-epiglottic fold* and two lateral *pharyngo-epiglottic folds.* The depression on each side of the glosso-epiglottic fold is named the *vallecula.* The lower part of the anterior surface lies behind the hyoid bone and the thyrohyoid membrane, and is connected to the upper border of the hyoid bone by an elastic ligament,

Fig. 1086.—The arytenoid and cricoid cartilages.



A, the left arytenoid cartilage, medial aspect. *B*, the right arytenoid cartilage, medial aspect. *C*, the cricoid cartilage, posterior aspect. *D*, the cricoid cartilage, left lateral aspect.

named the *hyo-epiglottic ligament*; it is separated from the thyrohyoid membrane by some fatty tissue.

The *posterior surface* of the epiglottis is smooth, concave from side to side, concavoconvex from above downwards, and covered with mucous membrane; its lower part projects backwards as an elevation, known as the *tubercle.* When the mucous membrane is removed, the cartilage is seen to be indented by a number of small pits in which mucous glands are lodged.

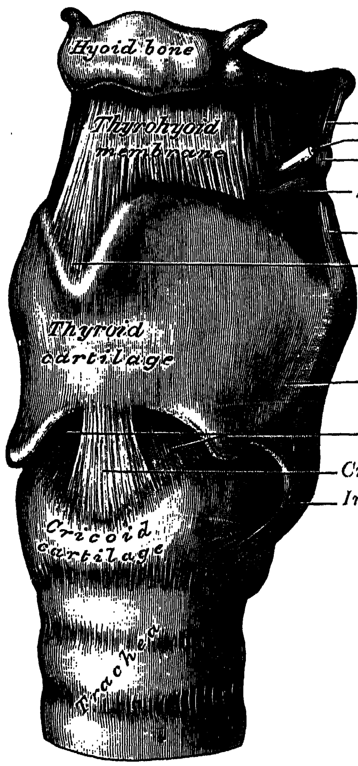
Structure.—The corniculate and cuneiform cartilages, the epiglottis, and the apices of the arytenoids consist of yellow fibrocartilage, which shows little tendency to calcification. The thyroid, cricoid, and the greater part of the arytenoids consist of hyaline cartilage, and become more or less ossified as age advances. Ossification commences about the twenty-fifth year in the thyroid cartilage, and somewhat later in the cricoid and the arytenoids; by the sixty-fifth year these cartilages may be completely converted into bone.

Joints.—The joints between the inferior horns of the thyroid cartilage and the sides of the cricoid cartilage are synovial, and each is enveloped by a capsular ligament, which is strengthened posteriorly by a fibrous band. Rotatory and gliding movements occur at these joints. The rotatory movement is one in which the cricoid cartilage rotates upon the inferior horns of the thyroid cartilage around an axis passing transversely through both joints. The gliding movement consists in a limited shifting of the cricoid on the thyroid in different directions.

A pair of synovial joints exist between the facets on the upper border of the lamina of the cricoid cartilage and the bases of the arytenoid cartilages; each joint is enclosed by a capsular ligament, and a strong *posterior crico-*

arytenoid ligament connects the cricoid cartilage with the medial and posterior part of the base of the arytenoid cartilage. These joints permit of two varieties of movement: one is a rotation of the arytenoid on a vertical axis, whereby the vocal process is moved laterally or medially, and the rima glottidis increased or diminished; the other is a gliding movement, and allows the arytenoid cartilages to approach or recede from each other; from the direction and slope of the articular surfaces lateral gliding is accompanied by a forward and downward movement. The two movements of gliding and rotation are associated, the medial gliding being connected with medial rotation, and the lateral gliding with lateral rotation. The posterior crico-arytenoid ligaments limit the forward movements of the arytenoid cartilages on the cricoid cartilage.

FIG. 1087.—The ligaments of the larynx. Anterolateral aspect.



A cartilaginous, sometimes a synovial, joint exists between the apex of each arytenoid cartilage and the corresponding corniculate cartilage, and a Y-shaped ligament, termed the *cricopharyngeal ligament*, unites the apices of the corniculate cartilages to the upper border of the lamina of the cricoid cartilage.

Ligaments and membranes.—The ligaments of the larynx (figs. 1087, 1088) are (*a*) *extrinsic*, those connecting the thyroid cartilage and epiglottis with the hyoid bone, and the cricoid cartilage with the trachea; and (*b*) *intrinsic*, those uniting the cartilages of the larynx to one another.

Extrinsic ligaments.—The thyroid cartilage is connected to the hyoid bone by the thyrohyoid membrane, and by a median and two lateral thyrohyoid ligaments.

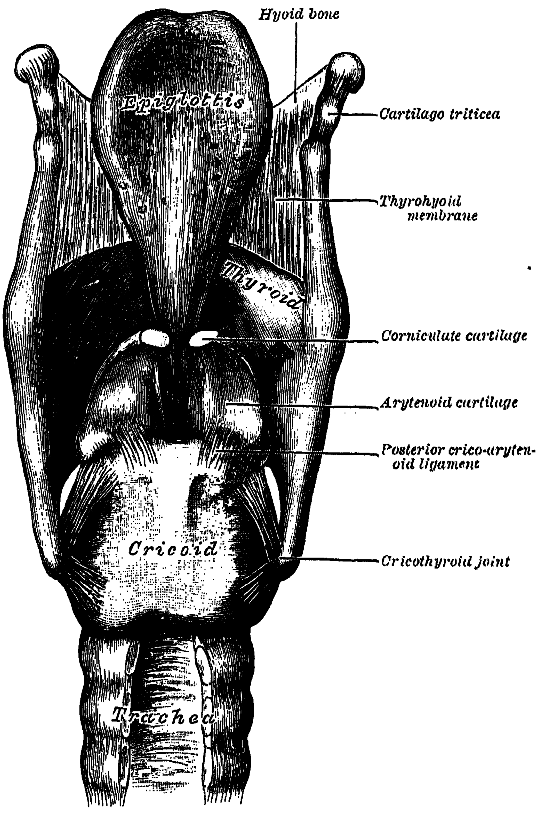
The *thyrohyoid membrane* is a broad, fibro-elastic layer, attached below to the upper border of the thyroid cartilage and to the front of its superior horns, and above to the upper margin of the posterior surface of the body and greater horns of the hyoid bone. As it ascends, it passes behind the posterior surface of the body of the hyoid bone, and is separated from it by a bursa, which facilitates the upward movement of the larynx during deglutition. The middle, thicker, part of the membrane is termed the *median thyrohyoid ligament*; on

each side the lateral thinner portion is pierced by the superior laryngeal vessels and the internal laryngeal nerve. Its outer surface is in relation with the Thyrohyoid, Sternohyoid and Omohyoid muscles, and with the body of the hyoid bone.

The *lateral thyrohyoid ligaments* are round elastic cords which form the posterior borders of the thyrohyoid membrane, and connect the tips of the superior horns of the thyroid cartilage to the posterior ends of the greater horns of the hyoid bone. A small cartilaginous nodule, termed the *cartilago triticea*, is frequently found in each ligament.

The epiglottis is attached to the hyoid bone by the hyo-epiglottic ligament, and to the thyroid cartilage by the thyro-epiglottic ligament (p. 1230).

FIG. 1088.—The ligaments of the larynx. Posterior aspect.



The *cricotracheal ligament* unites the lower border of the cricoid cartilage with the first ring of the trachea. It is continuous below with the fibrous membrane which invests the rings of the trachea.

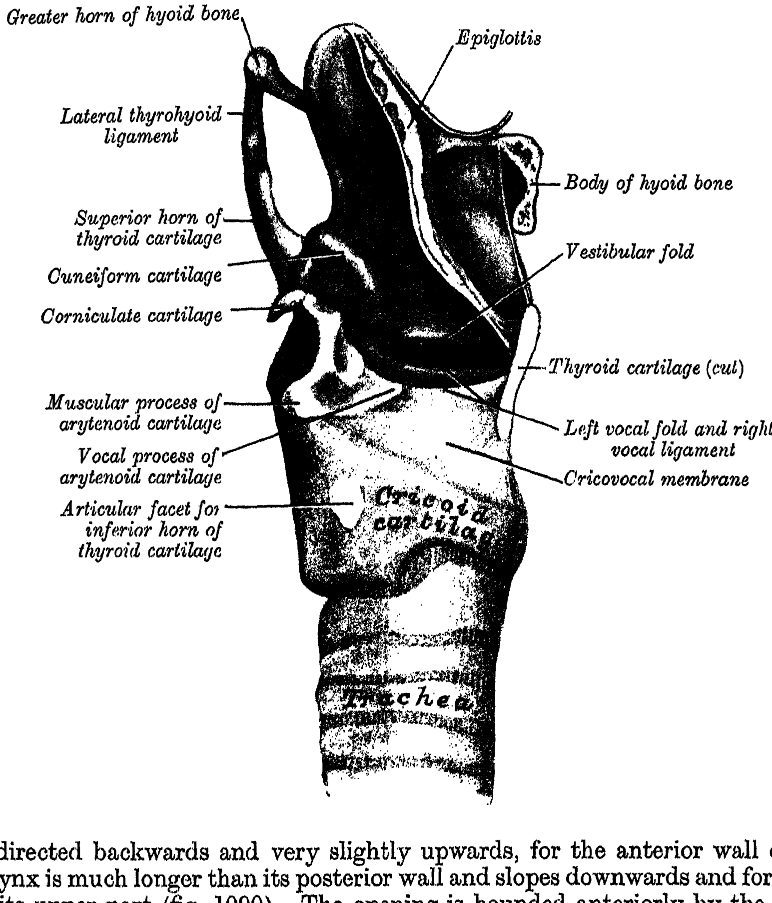
Intrinsic ligaments.—Beneath the mucous membrane of the larynx there is a broad sheet of fibrous tissue which contains many elastic fibres, and is termed the *elastic membrane of the larynx*. It is subdivided on each side by the interval between the vestibular (ventricular) and vocal ligaments; the upper portion extends between the arytenoid cartilage and the cartilage of the epiglottis, and is often poorly defined; the lower part is a well-marked membrane forming, with its fellow of the opposite side, the cricovocal membrane (conus elasticus), which connects the thyroid, cricoid, and arytenoid cartilages one to another. The joints between the individual cartilages are also provided with ligaments, already described.

The *cricovocal membrane* (conus elasticus) (fig. 1089) is composed mainly of yellow elastic tissue. It consists of an anterior and two lateral parts. The *anterior* part, or *cricothyroid ligament*, is thick and strong, narrow above and broad below. It connects the front parts of the contiguous margins of the thyroid and cricoid cartilages. It is overlapped on each side by the Cricothyroid, but between these muscles it is subcutaneous; its upper part is crossed by a small arterial arch, formed by the junction of the two cricothyroid arteries; branches of this arch pierce the ligament. The *lateral* part of the cricovocal membrane is thinner; it is lined with the mucous membrane of the larynx, and is covered with the Cricoarytænoideus lateralis and Thyreoarytænoideus. It extends upwards and medially from the inner edge of the superior border of the cricoid cartilage, and is attached, in front, to the deep surface of the thyroid angle and, behind, to the inferior surface and tip of the vocal process of the arytenoid cartilage. *Between these two attachments, the upper edge of the lateral part of the cricovocal membrane is free and is thickened slightly to form the* vocal ligament (fig. 1089).

Cavum laryngis (figs. 1090, 1091).—The *cavity of the larynx* extends from the laryngeal inlet, by which it communicates with the pharynx, to the level of the lower border of the cricoid cartilage, where it is continuous with the cavity of the trachea. It is divided into three parts by an upper and a lower pair of folds of mucous membrane which project from the sides of the cavity into its interior. The upper folds are named the *vestibular folds* (ventricular folds), and the fissure between them is called the *rima vestibuli*. The lower folds are concerned in the production of the voice, and are therefore named the *vocal folds*, and the fissure between them is called the *rima glottidis*.

The *inlet of the larynx* [aditus laryngis] (fig. 1092) is the aperture through which the laryngeal cavity opens into the pharynx. The plane of the aperture

Fig. 1089.—A dissection to show the right half of the cricovocal membrane. The right lamina of the thyroid cartilage and the subjacent muscles have been removed.



is directed backwards and very slightly upwards, for the anterior wall of the larynx is much longer than its posterior wall and slopes downwards and forwards in its upper part (fig. 1090). The opening is bounded anteriorly by the upper edge of the epiglottis, posteriorly by the mucous membrane stretching between the arytenoid cartilages, and on each side by the free edge of a fold of mucous membrane which stretches between the side of the epiglottis and the apex of the arytenoid cartilage and contains some ligaments and muscular fibres ; this is the *aryepiglottic fold*, and on the posterior part of its free margin there are two oval elevations, an anterior produced by the cuneiform cartilage, and a posterior by the corniculate cartilage. These elevations are separated by a shallow vertical furrow, which is continuous below with the opening into the sinus (ventricle) of the larynx.

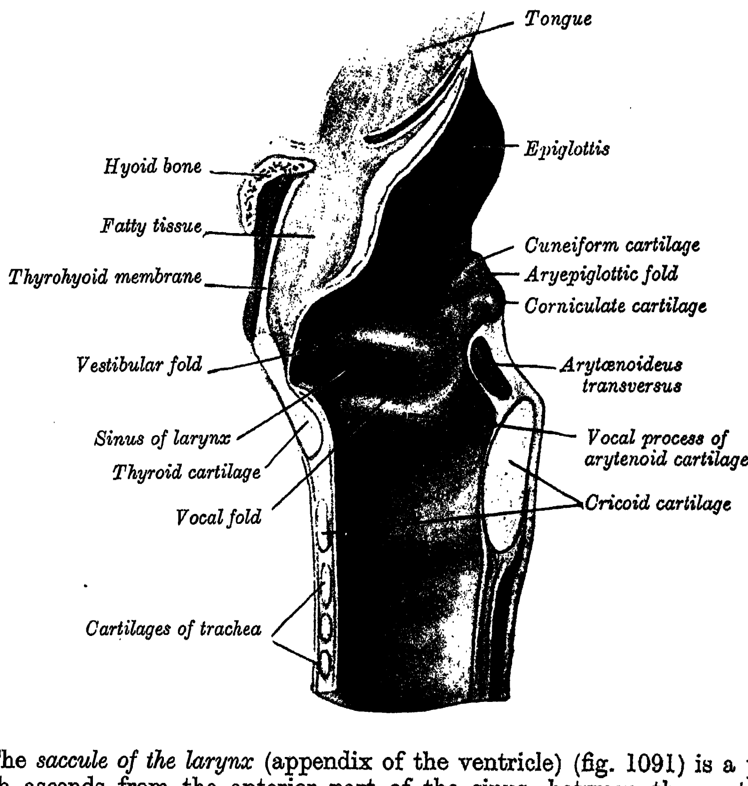
The *vestibule of the larynx* (figs. 1090, 1091) is the part between the laryngeal inlet and the level of the vestibular folds ; it is wide above, and narrow below. Its anterior wall is much deeper than its posterior wall and consists of the posterior surface of the epiglottis, the lower part of which projects backwards,

as the tubercle (p. 1230). Its lateral walls, deep in front and shallow behind, are formed by the medial surfaces of the aryepiglottic folds; its posterior wall consists of the mucous membrane connecting the arytenoid cartilages, above the level of the vestibular folds.

The *middle part* of the laryngeal cavity is the smallest. It reaches from the level of the rima vestibuli to that of the rima glottidis. On each side it opens, through a slit between the vestibular and vocal folds, into a recess which is named the sinus of the larynx.

The *sinus* (ventricle) *of the larynx* (figs. 1090, 1091) is a fusiform recess on each side, between the vestibular and vocal folds, and ascending for a short distance outside the vestibular fold. It is lined with mucous membrane, lateral to which is the corresponding Thyroarytenoid muscle. From the anterior part of the sinus a narrow opening leads upwards into the saccule of the larynx.

FIG. 1090.—A sagittal section through the larynx.



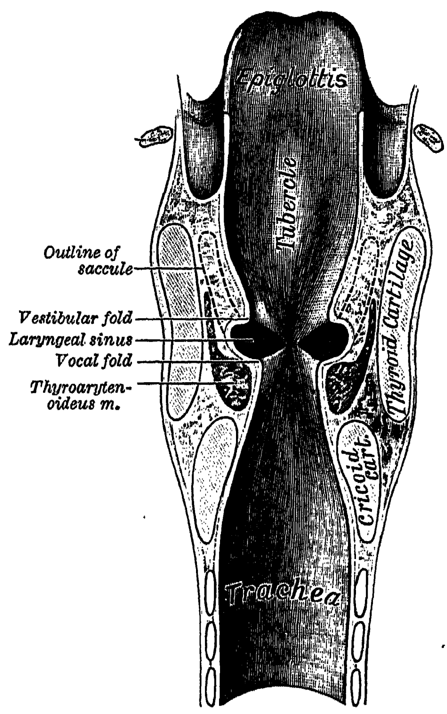
The *saccule of the larynx* (appendix of the ventricle) (fig. 1091) is a pouch which ascends from the anterior part of the sinus, between the vestibular fold and the inner surface of the thyroid cartilage, occasionally extending as high as the upper border of the cartilage; it is conical in form, and curved slightly backwards. On the surface of its mucous membrane there are the openings of sixty or seventy mucous glands, which are lodged in the submucous areolar tissue. The saccule is enclosed in a fibrous capsule continuous below with the vestibular ligament. Its medial surface is covered by a few delicate muscular fasciculi, which arise from the apex of the arytenoid cartilage and, passing forwards between the saccule of the larynx and the mucous membrane of the vestibule, become lost in the aryepiglottic fold; laterally it is separated from the thyroid cartilage by the Thyreoepiglotticus. These muscles compress the sac and express the secretion of its glands upon the vocal fold to lubricate its surfaces.

The *vestibular folds* (ventricular folds) (figs. 1089, 1090, 1091) are two thick folds of mucous membrane, each enclosing a narrow band of fibrous tissue, termed the *vestibular ligament*, which is fixed in front to the angle of the thyroid cartilage immediately below the attachment of the epiglottic cartilage, and

behind to the anterolateral surface of the arytenoid cartilage, a short distance above the vocal process.

The *vocal folds* (figs. 1089, 1090, 1091) are two sharp folds of mucous membrane which stretch from the angle of the thyroid cartilage, at about its middle, to the vocal processes of the arytenoid cartilages. They form the lateral boundaries of the rima glottidis in its anterior part and are intimately concerned in the production of the voice. The epithelium which covers the vocal fold is of the stratified squamous type and is closely bound down to the underlying vocal ligament. As a result of the absence of a submucous layer with its contained blood-vessels, the vocal fold is pearly white in colour in the living subject. The *vocal ligament*, which is continuous below with the lateral part of the cricovocal membrane (conus elasticus) (p. 1232), consists of a band of yellow elastic tissue, related, on its lateral side, to the Vocalis muscles (p. 1238).

FIG. 1091.—A coronal section through the larynx and the upper part of the trachea.



The *rima glottidis* (fig. 1093) is a fissure situated between the vocal folds anteriorly, and between the bases and vocal processes of the arytenoid cartilages posteriorly; it is limited behind by the mucous membrane passing between the arytenoid cartilages, at the level of the vocal folds. The portion between the vocal folds is named the *intermembranous part*, and measures about three-fifths of the length of the entire aperture; that between the arytenoid cartilages is named the *intercartilaginous part*. The average length of the rima glottidis, in the adult male, is 23 mm.; in the adult female, 17 mm. It is the narrowest part of the larynx, but its width and shape vary with the movements of the vocal folds and arytenoid cartilages during respiration and phonation. In the condition of rest, as in quiet respiration, the intermembranous part is triangular, with its apex in front and its base behind—the latter being represented by a line, about 8 mm. long, connecting the anterior ends of the vocal processes—while the medial surfaces of the arytenoid cartilages are parallel to each other and hence the intercartilaginous part is rectangular. During extreme adduction of the vocal folds, as in the production of a high note, the intermembranous part of the rima glottidis is reduced to a linear slit by the approximation of the vocal folds, while the intercartilaginous part becomes triangular, its apex corresponding to the anterior ends of the vocal processes of the arytenoid cartilages, which are brought close together by the medial rotation of the cartilages. Conversely, in extreme abduction of the vocal folds, as in forced inspiration, the arytenoid cartilages are rotated laterally, and their vocal processes are drawn widely apart, with the result that the intercartilaginous part is triangular in shape but with its apex directed backwards. In this condition the rima glottidis is somewhat lozenge-shaped, the sides of the intermembranous part diverging from before backwards, those of the intercartilaginous part diverging from behind forwards—the widest part of the aperture corresponding with the attachments of the vocal folds to the vocal processes.

The *lower part* of the laryngeal cavity extends from the level of the vocal folds to the lower border of the cricoid cartilage. Its upper part is elliptical in form, but its lower part widens, assumes a circular shape, and is continuous with the cavity of the trachea. It is lined with mucous membrane, and its

walls consist of the cricovocal membrane (conus elasticus) above, and the inner surface of the cricoid cartilage below.

Muscles.—The muscles of the larynx are divisible into two groups :—(1) *extrinsic* and (2) *intrinsic.*

(1) The extrinsic muscles pass between the larynx and neighbouring structures, and are described in the section on Myology.

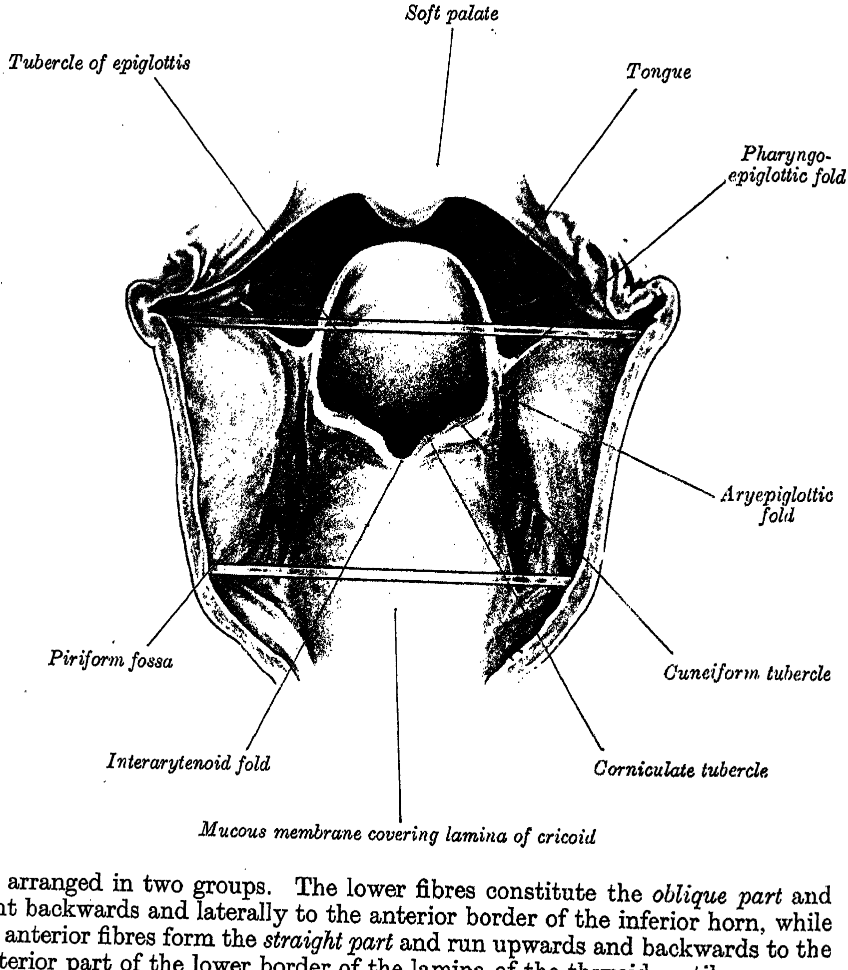
(2) The intrinsic muscles are :

Cricothyreoideus	Arytænoideus transversus.
pars obliqua,	Arytænoideus obliquus.
pars recta.	Aryepiglotticus.
Cricoarytænoideus posterior.	Thyreoarytænoideus.
Cricoarytænoideus lateralis.	Vocalis.
Thyreoepiglotticus.	

With the exception of the Arytænoideus transversus these muscles are paired.

The *Cricothyroid* (fig. 1094), triangular in form, arises from the front and lateral part of the outer surface of the cricoid cartilage ; its fibres diverge, and

FIG. 1092.—The inlet of the larynx, viewed from behind. The posterior wall of the pharynx has been divided in the median plane and two glass rods have been inserted to keep the cut portions apart.



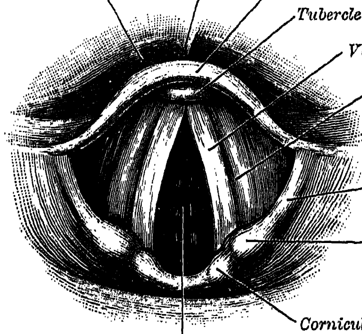
are arranged in two groups. The lower fibres constitute the *oblique part* and slant backwards and laterally to the anterior border of the inferior horn, while the anterior fibres form the *straight part* and run upwards and backwards to the posterior part of the lower border of the lamina of the thyroid cartilage.

The medial borders of the two muscles are separated by a triangular interval occupied by the subcutaneous part of the cricothyroid ligament.

The *Cricoarytænoideus posterior* (fig. 1095) arises from the lower and medial part of the broad depression on the corresponding half of the posterior surface

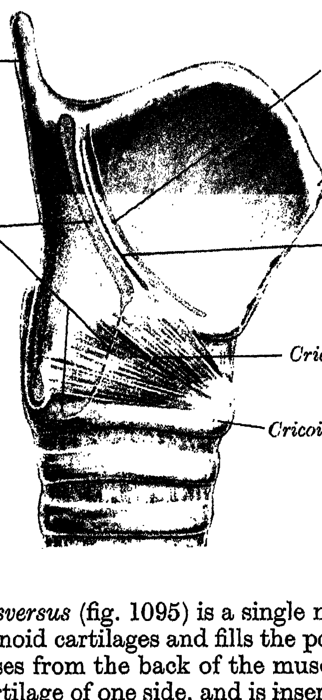
of the lamina of the cricoid cartilage ; its fibres, directed upwards and laterally, converge to be inserted into the back of the muscular process of the arytenoid cartilage. The highest fibres are nearly horizontal, the middle oblique and the lowest almost vertical.

FIG. 1093.—A laryngoscopic view of the interior of the larynx.



The *Cricoarytænoideus lateralis* (fig. 1096) is smaller than the preceding muscle ; it arises from the upper border of the arch of the cricoid cartilage, and, passing obliquely upwards and backwards, is inserted into the front of the muscular process of the arytenoid cartilage.

FIG. 1094.—A side view of the larynx, showing the muscular attachments.



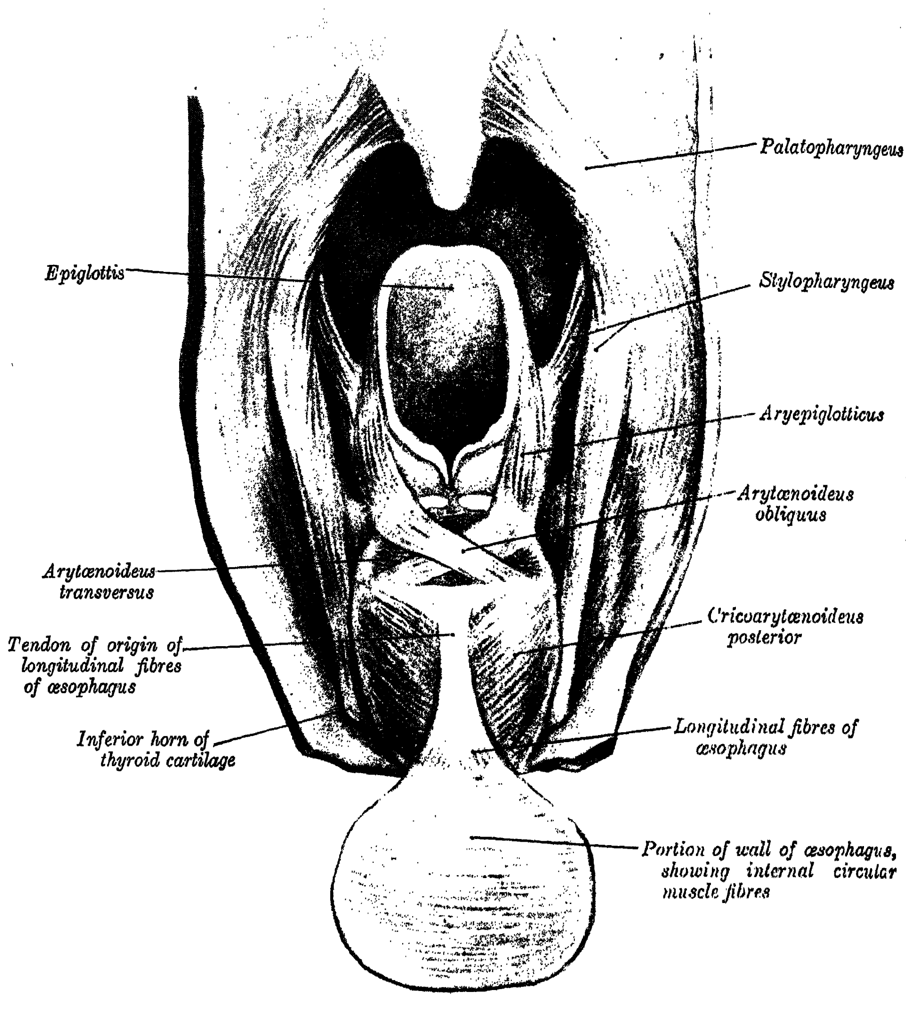
The *Arytænoideus transversus* (fig. 1095) is a single muscle which bridges the interval between the arytenoid cartilages and fills the posterior concave surfaces of these cartilages. It arises from the back of the muscular process and lateral border of the arytenoid cartilage of one side, and is inserted into the corresponding parts of the cartilage on the opposite side.

The *Arytænoideus obliquus* (fig. 1095), superficial to the Arytænoideus transversus, consists of two fasciculi which cross each other like the limbs of the letter X. Each passes from the back of the muscular process of one arytenoid cartilage to the apex of the opposite cartilage. Some of the fibres are continued

round the lateral margin of the apex of the arytenoid cartilage, and are prolonged into the aryepiglottic fold; they constitute the *Aryepiglotticus* muscle.

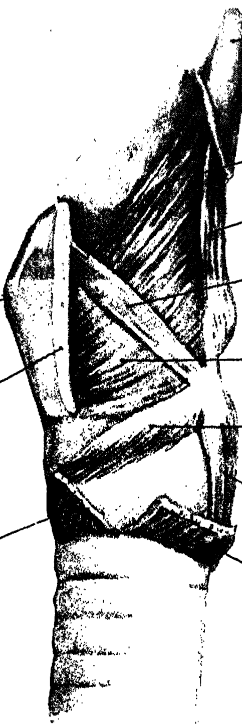
The *Thyreoarytænoideus* (fig. 1096) is a broad, thin muscle, which is situated lateral to the vocal fold, the cricovocal membrane, the sinus and the saccule of the larynx. It arises in front from the lower half of the angle of the thyroid cartilage, and from the cricothyroid ligament. Its fibres pass backwards, laterally and upwards, to be inserted into the anterolateral surface of the arytenoid cartilage. The lower and deeper fibres of the muscle form a band which, in a coronal section, appears as a triangular bundle, and is attached to the lateral surface of the vocal process and to the inferior impression on the anterolateral surface of the arytenoid cartilage. This bundle is named the *Vocalis* muscle, and is parallel with, and just lateral to, the vocal ligament. The Vocalis is thicker behind than in front, because many of its deeper fibres take origin from the vocal ligament, and so do not extend so far forwards as the thyroid cartilage. A considerable number of the fibres of the Thyreoarytænoideus are prolonged into the aryepiglottic fold, where some of them are lost, while others are continued to the margin of the epiglottis, forming the *Thyreoepiglotticus*. A few fibres extend along the wall of the sinus (ventricle) from the lateral margin of the arytenoid cartilage to the side of the epiglottis. The *Thyreoarytænoideus superior* (fig. 1096) is not always present.

FIG. 1095.—The muscles of the larynx. Posterior aspect.



Actions.—The muscles of the larynx may be conveniently divided into three groups, (1) those which open and close the glottis, viz. the Cricoarytænoidei posteriores et laterales and the Arytænoidei ; (2) those which regulate the degree of tension of the vocal ligaments, viz. the Cricothyreoidei, the Thyreoarytænoidei, and the Vocales ; (3) those which modify the inlet of the larynx, viz. the Aryepiglottici and the Thyreoepiglottici.

FIG. 1096.—The muscles of the larynx. Lateral aspect. The left lamina of the thyroid cartilage has been removed.



The *Cricoarytænoidei posteriores* open the glottis, by rotating the arytenoid cartilage laterally around a vertical axis passing through the crico-arytenoid joints, so that the vocal processes and the attached vocal folds are separated.

The *Cricoarytænoidei laterales* close the glottis, by rotating the arytenoid cartilages medially so as to approximate the vocal processes.

The *Arytænoideus transversus* approximates the arytenoid cartilages, and thus closes the opening of the glottis, especially at its posterior part.

The *Cricothyroids* produce tension and elongation of the vocal ligaments by drawing up the arch of the cricoid cartilage and tilting back the upper border of its lamina ; the distance between the vocal processes and the angle of the thyroid is thus increased, and the vocal ligaments are consequently put on the stretch.

The *Thyreoarytænoidei* draw the arytenoid cartilages forwards towards the thyroid, and thus shorten and relax the vocal ligaments. At the same time they rotate the arytenoid cartilages medially and approximate the vocal folds. The deeper fibres, forming the *Vocales*, produce relaxation of the posterior parts of the vocal ligaments, while the anterior part is tense, the effect being to raise the pitch of the voice.

The *Arytænoidei obliqui* and the *Aryepiglottici* act as a sphincter of the inlet of the larynx, by bringing the aryepiglottic folds together, and by approximating the arytenoid cartilages to the tubercle of the epiglottis.

The *Thyreoepiglottici* tend to widen the inlet of the larynx by their action on the aryepiglottic folds.

The manner in which the inlet of the larynx is closed during deglutition is referred to on p. 1299.

Mucous Membrane.—The mucous membrane of the larynx is continuous above with that of the mouth and pharynx, below with that of the trachea. It is loosely attached to the anterior surface of the epiglottis, and to the underlying tissues in the valleculæ. It covers the aryepiglottic folds, which bound the inlet of the larynx ; in these folds there

is a considerable amount of areolar tissue. It lines the cavity of the larynx, forms, by its reduplication, the chief parts of the vestibular folds, and is continued into the sinus and saccule of the larynx. It is firmly attached to the posterior surface of the epiglottis and to the laryngeal surfaces of the cuneiform and arytenoid cartilages. The parts covering the vocal ligaments are thin and intimately adherent to them. On the anterior surface, and the upper half of the posterior surface, of the epiglottis, the upper part of the aryepiglottic folds, and the vocal folds, the epithelium of the mucous membrane is of the stratified squamous type; patches of stratified squamous epithelium are also found above the glottis. The rest of the laryngeal mucous membrane is covered with ciliated columnar epithelium.

Glands.—The mucous membrane of the larynx is furnished with numerous mucous glands; they are very plentiful upon the epiglottis, where they are lodged in little pits; many are present in the margins of the aryepiglottic folds in front of the arytenoid cartilages, where they are termed the *arytenoid glands*. They are large and numerous in the saccules of the larynx. The free edges of the vocal folds are devoid of glands.

Taste-buds, similar to those in the tongue, are scattered over the posterior surface of the epiglottis, in the aryepiglottic folds, and less regularly in some other parts of the larynx.

Vessels and Nerves.—The chief *arteries* of the larynx are the laryngeal branches of the superior and inferior thyroid arteries. The *veins* accompanying the superior laryngeal artery join the superior thyroid vein, which opens into the internal jugular vein; those accompanying the inferior laryngeal artery join the inferior thyroid vein, which opens into the innominate vein. The *lymph vessels* are divisible into two sets, a superior above the vocal folds, and an inferior below; the superior vessels accompany the superior laryngeal artery, pierce the thyrohyoid membrane, and end in the deep cervical lymph glands situated near the bifurcation of the common carotid artery; some of the inferior lymph vessels pierce the cricothyroid ligament and open into a lymph gland lying in front of that ligament or in front of the upper part of the trachea, while others emerge below the cricoid cartilage and pass to the deep cervical lymph glands and to the lymph glands alongside of the inferior thyroid artery. The *nerves* are derived from the internal and external branches of the superior laryngeal nerve, from the recurrent laryngeal nerve and from the sympathetic. The internal laryngeal branch is almost entirely sensory, but some motor filaments are said to be carried by it to the Arytænoideus. It enters the larynx through the postero-inferior part of the thyrohyoid membrane above the superior laryngeal artery, and divides into branches which supply both surfaces of the epiglottis, the aryepiglottic fold, and the interior of the larynx down as far as the level of the vocal folds. The external laryngeal branch supplies the Cricothyroid by entering its lateral surface. The terminal part of the recurrent laryngeal nerve accompanies the laryngeal branch of the inferior thyroid artery, and passes upwards deep to the lower border of the Constrictor pharyngis inferior, immediately behind the cricothyroid joint. It supplies all the intrinsic muscles of the larynx except the Cricothyroid, and distributes sensory branches to the laryngeal mucous membrane below the level of the vocal folds. See also footnote, p. 1073.

Laryngoscopic examination.—The inlet of the larynx, the structures surrounding it, and the cavity of the larynx can be inspected with the laryngoscope. The epiglottis is much foreshortened (fig. 1093), but its tubercle can be seen in the median plane. From the margins of the epiglottis the aryepiglottic folds can be traced backwards and medially and, at their posterior extremities, the elevations produced by the cuneiform and the corniculate cartilages can be recognised. Both the vestibular and the vocal folds are visible within the cavity of the larynx and, when the rima glottidis is opened widely, the rings of the trachea come into view.

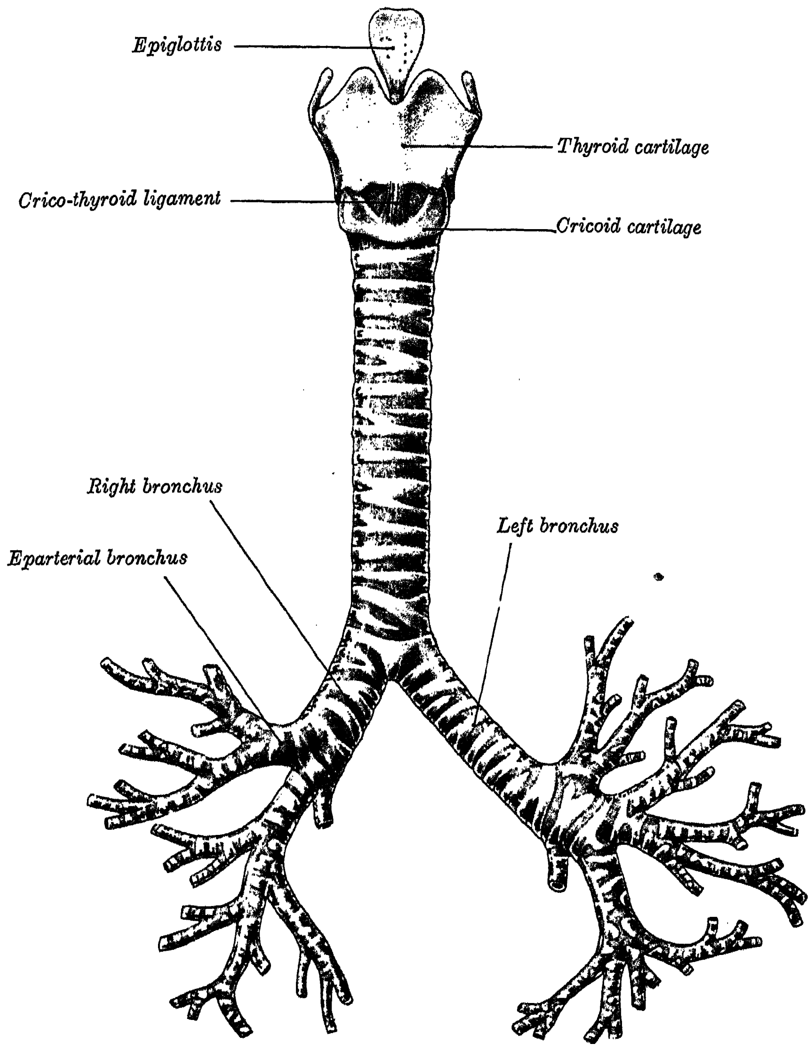
The Trachea and Bronchi (fig. 1097)

The trachea, or windpipe, is a cartilaginous and membranous tube, about 10 or 11 cm. long, continued downwards from the lower part of the larynx, and reaching from the level of the sixth cervical vertebra to that of the upper border of the fifth thoracic vertebra, where it divides into two bronchi, one for each lung. The point of bifurcation usually lies a little to the right of the median plane. The trachea is not quite cylindrical, being flattened posteriorly; its diameter from side to side is about 2 cm. in the adult male, and 1·5 in the adult female. In the child the trachea is smaller, more deeply placed and more movable than in the adult.

Relations of the trachea.—The *cervical part* of the trachea (fig. 1098) presents the following relations. Anteriorly it is covered with the skin, the superficial and deep fasciæ, crossed by the jugular arch connecting the anterior jugular veins and overlapped by the Sternohyoid and Sternothyroid muscles. The second, third and fourth rings of the trachea are crossed by the isthmus of the thyroid gland, and immediately above the isthmus by an anastomosing

vessel which connects the two superior thyroid arteries ; below the isthmus it is related, in front, to the pretracheal fascia, the inferior thyroid veins, the remains of the thymus, and the arteria thyreoidea ima (when that vessel exists). In the child, the innominate artery crosses obliquely in front of the trachea at, or a little above, the level of the upper border of the manubrium sterni. Posteriorly the trachea is related to the œsophagus, which intervenes between it

FIG. 1097.—The cartilages of the larynx, trachea, and bronchi. Anterior aspect.

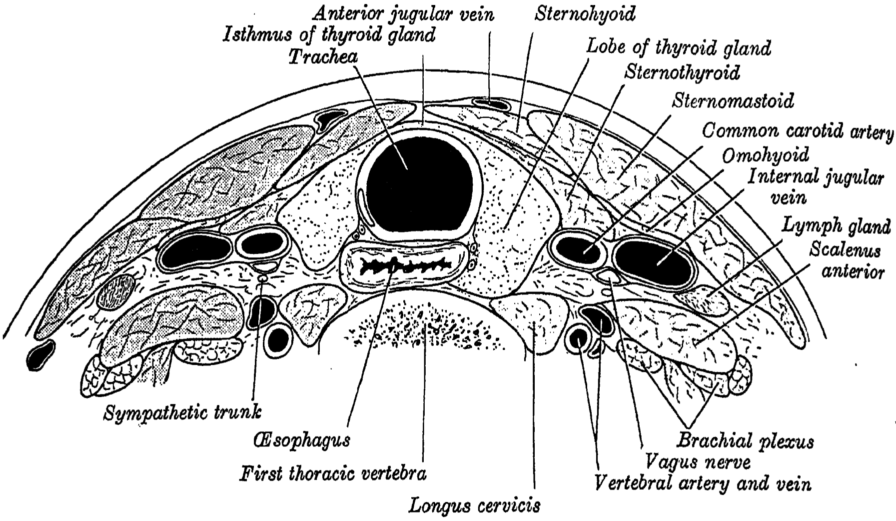


and the vertebral column ; the recurrent laryngeal nerves ascend, one on each side, in the grooves between the sides of the trachea and the œsophagus. *Laterally* the trachea is related to the lobes of the thyroid gland, which descend to the level of the fifth or sixth tracheal ring, and to the common carotid and inferior thyroid arteries.

The *thoracic part* of the trachea (figs. 1099, 1100) descends through the superior mediastinum. *In front*, its *upper* portion is related to the manubrium sterni, the origins of the Sternothyroid muscles, the remains of the thymus, and the inferior thyroid veins ; and its *lower* portion, to the left innominate vein, the arch of the aorta, the innominate and left common carotid arteries, the deep part of the cardiac plexus of nerves, and some lymph glands. Owing to the divergence of the innominate and left common carotid arteries as they

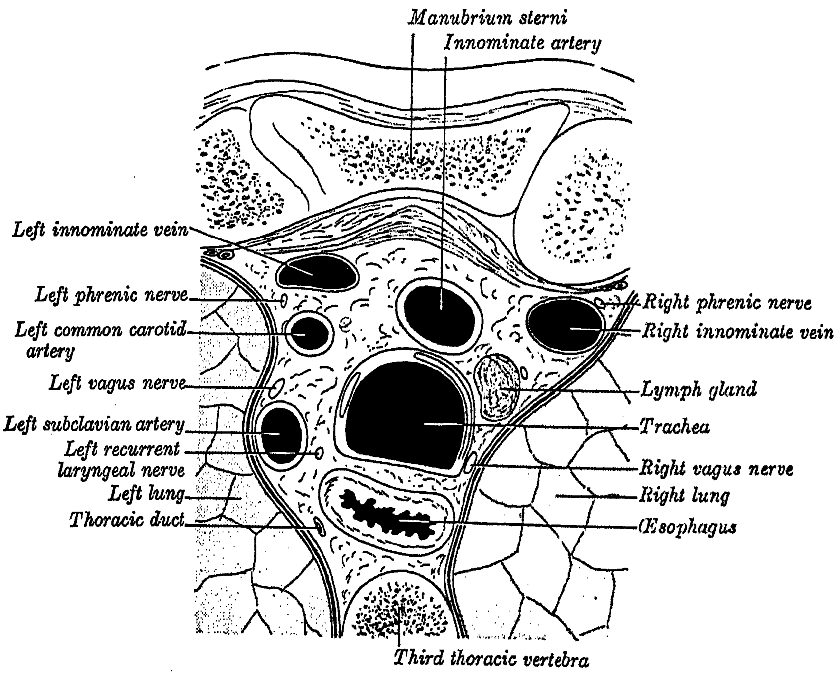
ascend in the neck, the former vessel comes to lie on the right, and the latter on the left of the trachea. *Behind*, it is related to the œsophagus, by which it is

FIG. 1098.—A transverse section through the anterior part of the neck at the level of the body of the first thoracic vertebra.



separated from the vertebral column. On the *right* it is related to the right lung and pleura, the right vagus nerve, and the azygos vein : on the left to the arch of the aorta, the left common carotid and left subclavian arteries. The left

FIG. 1099.—A transverse section through the mediastinum at the level of the body of the third thoracic vertebra.

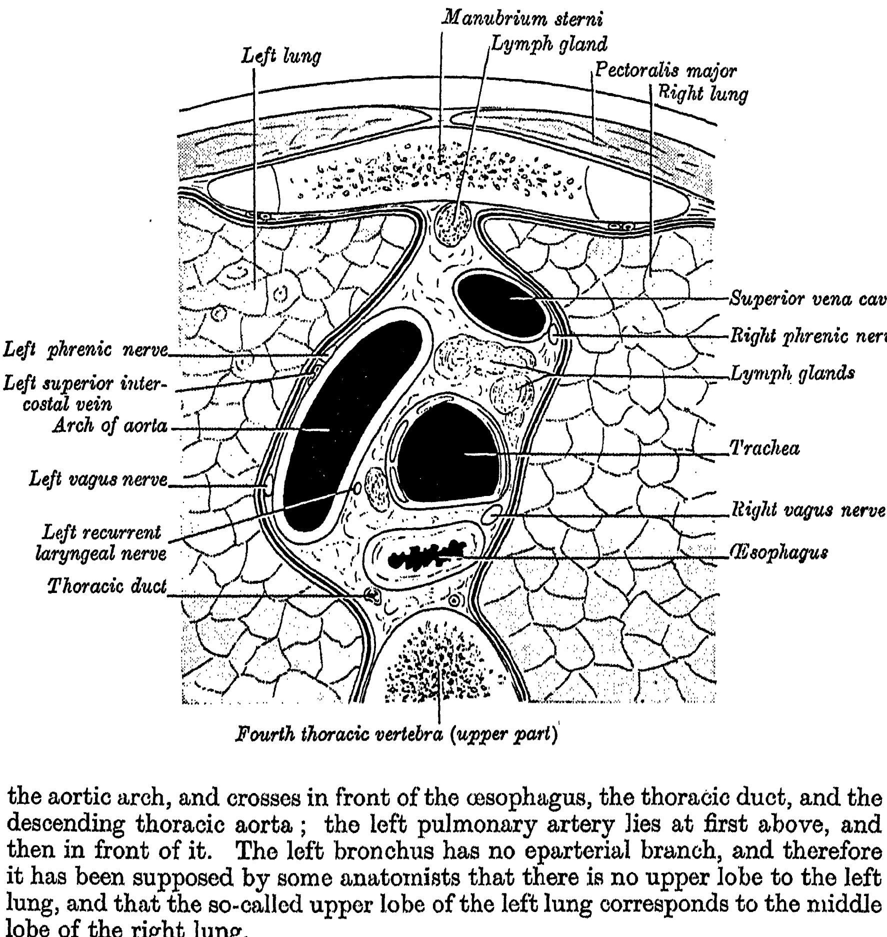


recurrent laryngeal nerve, in its upward course, lies at first between the trachea and the arch of the aorta, and then in the groove between the trachea and the œsophagus.

The **right bronchus**, wider, shorter, and more vertical than the left, is about 2·5 cm. long, and enters the right lung nearly opposite the fifth thoracic vertebra. The azygos vein arches over it from behind ; the right pulmonary artery lies at first below and then in front of it. It gives off a branch to the upper lobe of the right lung ; this is termed the *eparterial bronchus*, because it arises above the right pulmonary artery. The bronchus now passes below the artery, and is known as the *hyparterial bronchus* ; this divides into two branches, one for the middle and the other for the lower lobe of the lung.

The **left bronchus**, narrower than the right, is nearly 5 cm. long, and enters the root of the left lung opposite the sixth thoracic vertebra. It passes below

FIG. 1100.—A transverse section through the mediastinum at the level of the upper part of the body of the fourth thoracic vertebra.



the aortic arch, and crosses in front of the œsophagus, the thoracic duct, and the descending thoracic aorta ; the left pulmonary artery lies at first above, and then in front of it. The left bronchus has no eparterial branch, and therefore it has been supposed by some anatomists that there is no upper lobe to the left lung, and that the so-called upper lobe of the left lung corresponds to the middle lobe of the right lung.

The further subdivision of the bronchi will be considered with the structure of the lung.

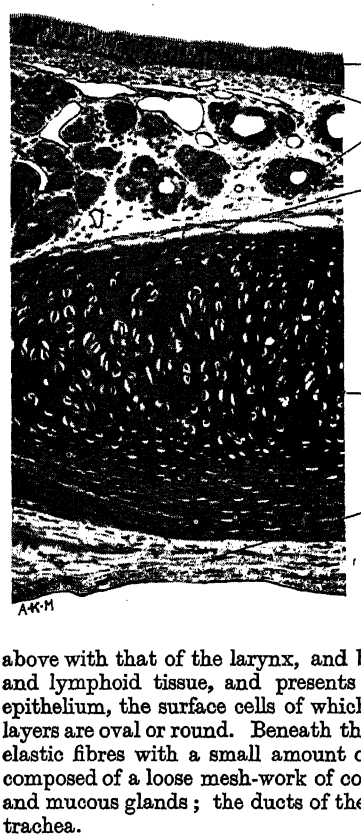
Structure (fig, 1101).—The trachea and extrapulmonary bronchi consist of a framework of imperfect rings of hyaline cartilage, united by fibrous and unstriped muscular tissue. They are lined by mucous membrane.

The *cartilages* of the trachea vary from sixteen to twenty in number. Each is an imperfect ring which occupies the anterior two-thirds or so of the circumference of the trachea ; behind, where the rings are deficient, the tube is flat, and is completed by fibrous tissue and unstriped muscular fibres. The cartilages are placed horizontally one above another, and are separated by narrow intervals. They measure about 4 mm. in depth and 1 mm. in thickness ; their external surfaces are flattened, but their internal surfaces are convex. Two or more of the cartilages often unite, partially or completely, and are sometimes bifurcated at their extremities. They are highly elastic, but may become calcified

in advanced life. In the bronchi the cartilages are shorter and narrower than those of the trachea, but have the same shape and arrangement.

The first and the last tracheal cartilages differ from the others (fig. 1097). The *first cartilage* is broader than the rest, and often divided at one end; it is connected by the cricotracheal ligament with the lower border of the cricoid cartilage, with which, or with the succeeding cartilage, it is sometimes blended. The *last cartilage* is thick and broad in the middle, where its lower border is prolonged into a triangular hook-shaped process which curves downwards and backwards between the two bronchi. It forms on each side an imperfect ring which encloses the commencement of the bronchus. The cartilage above the last is somewhat broader at its centre than the others.

FIG. 1101.—A transverse section through a part of the wall of the trachea.



The *fibrous membrane.*—The cartilages are enclosed in an elastic fibrous membrane which consists of two layers, one, the denser, passing over the outer surfaces of the rings, the other over the inner surfaces: at the upper and lower margins of the cartilages the two layers blend and form a stout membrane which connects the rings one with another. Where the cartilages are deficient posteriorly, the membrane forms a single layer.

The *muscular tissue* is placed within the fibrous membrane at the posterior part of the tube, and consists of two layers of non-striped muscle, longitudinal and transverse. The *longitudinal fibres* are external, and consist of a few scattered bundles. The *transverse fibres* (Trachealis muscle) are internal, and form a thin layer which not only extends between the ends of the cartilages but also passes across in the intervals between the cartilages.

Mucous Membrane.—The mucous membrane is continuous above with that of the larynx, and below with that of the bronchi. It consists of areolar and lymphoid tissue, and presents a well-marked basement-membrane, supporting an epithelium, the surface cells of which are columnar and ciliated, while those of the deeper layers are oval or round. Beneath the basement-membrane there is a layer of longitudinal elastic fibres with a small amount of intervening areolar tissue. The *submucous layer* is composed of a loose mesh-work of connective tissue, containing large blood-vessels, nerves and mucous glands; the ducts of the latter pierce the overlying layers and open into the trachea.

Vessels and Nerves.—The trachea is supplied with blood mainly by the inferior thyroid *arteries*. The *veins* end in the thyroid venous plexus. The *lymph vessels* pass to the pretracheal and paratracheal lymph glands. The *nerves* are derived from the vagi and the recurrent laryngeal nerves, and from the sympathetic trunks; they are distributed to the Trachealis muscle and between the epithelial cells.

Applied Anatomy.—Foreign bodies often find their way into the air-passages, and may become lodged in the inlet of the larynx, or in the rima glottidis. Unless they are speedily removed or an opening is made into the air-passages below the obstruction, so as to enable the patient to breathe, they may cause death from suffocation, especially when they consist of large, soft substances, such as pieces of meat. Smaller bodies, frequently of a hard nature, such as cherry or plum stones, small pieces of bone, buttons, etc., may find their way through the rima glottidis into the trachea or bronchi, or may lodge in the sinus of the larynx. The dangers then depend not so much upon the mechanical obstruction as upon reflex spasm of the glottis produced by the irritation of the foreign body.

Beneath the mucous membrane of the upper part of the air-passage there is a considerable amount of submucous tissue, which is liable to become much swollen from effusion in inflammatory affections, constituting the condition known as ‘ œdema of the glottis.’ This effusion does not extend below the level of the vocal folds, on account of the fact that the mucous membrane is closely adherent to these structures without the intervention of

any submucous tissue. In cases of œdema of the glottis in which it is necessary to open the air-passages to prevent suffocation the operation of laryngotomy is sufficient.

The air-passages may be opened in three different situations: by a vertical incision through the centre of the thyroid cartilage (*thyrotomy*); through the cricothyroid ligament (*laryngotomy*); or in some part of the trachea (*tracheotomy*).

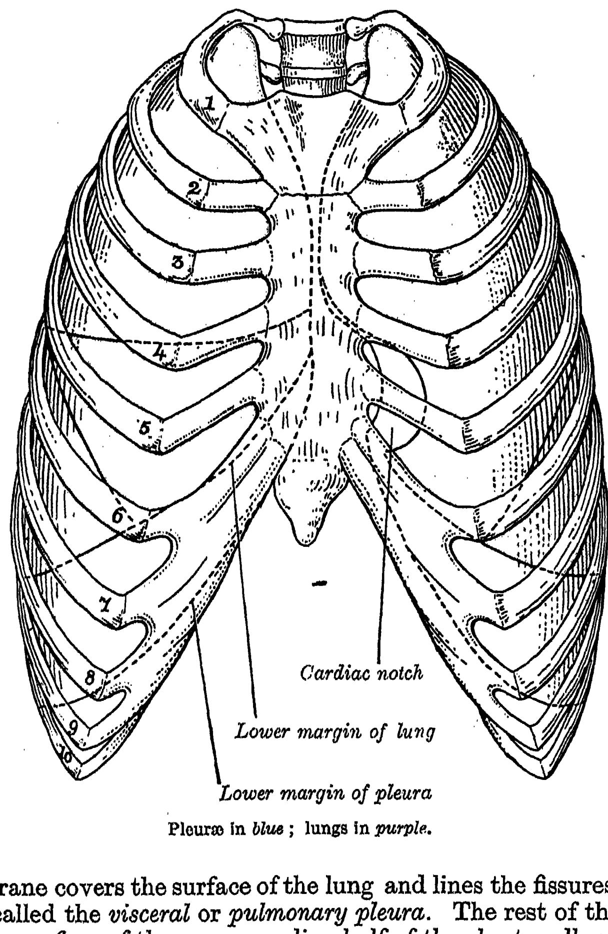
Tracheotomy may be performed either above or below the isthmus of the thyroid gland, or this structure may be divided and the trachea opened behind it. From the relations already described it must be evident that the trachea can be opened more readily above than below the isthmus.

After the trachea has been exposed it is transfixed with a sharp hook and drawn forwards in order to steady it. The knife is then inserted into the trachea and the upper two or three rings are divided in an upward direction.

The Pleuræ

Each lung is invested by a delicate serous membrane which is arranged in the form of a closed invaginated sac and is termed the **pleura.** A portion of this

Fig. 1102.—The relations of the pleuræ and lungs to the chest-wall. Anterior aspect.

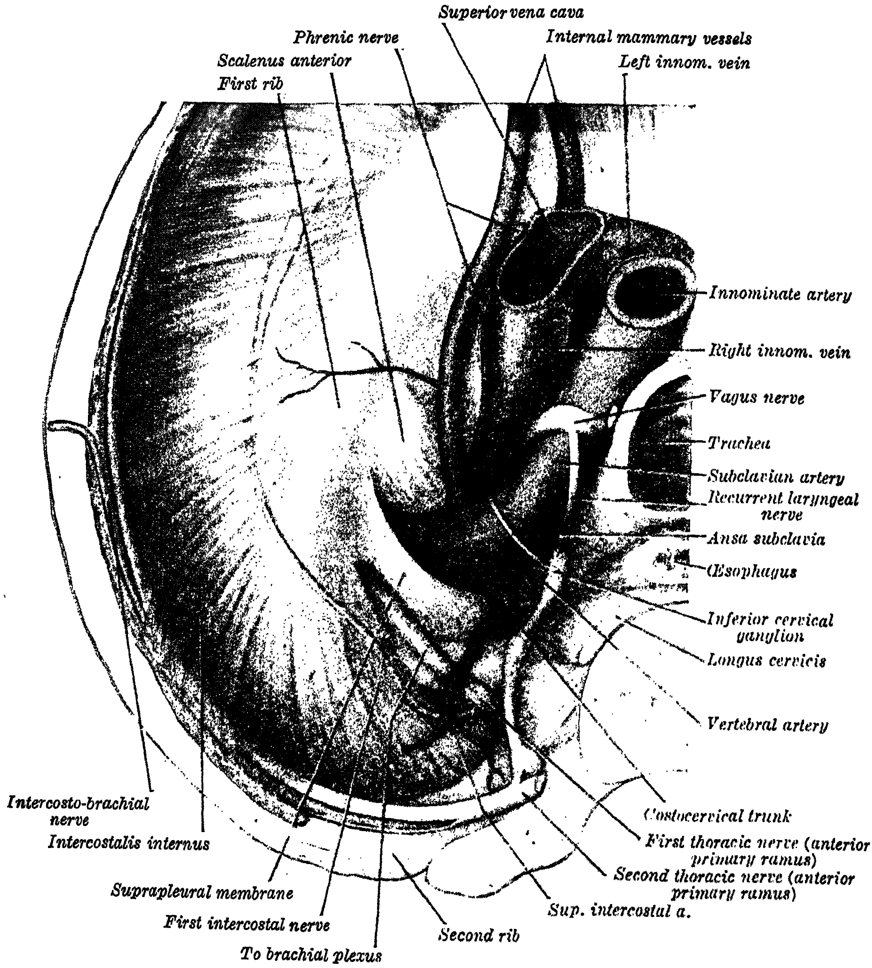


Pleuræ in *blue*; lungs in *purple*.

serous membrane covers the surface of the lung and lines the fissures between its lobes; it is called the *visceral* or *pulmonary pleura.* The rest of the membrane lines the inner surface of the corresponding half of the chest-wall, covers a large part of the Diaphragm, and is reflected over the structures occupying the middle part of the thorax; this portion is termed the *parietal pleura.* The pulmonary and parietal pleuræ are continuous with each other around and below the root of the lung; in health they are in actual contact, but the potential space between them is known as the *pleural cavity.* When the lung collapses or when air or fluid collects between the pulmonary and parietal pleuræ, the pleural cavity becomes apparent. The right and left pleural sacs are distinct from each other,

and come into immediate contact only for a short distance behind the upper half of the body of the sternum, although they are separated only by a narrow interval behind the œsophagus in the midthoracic region. The interval between the two sacs is named the *interpleural space*. The right pleural cavity is wider than the left, because the heart extends further to the left than to the right side. The upper and lower limits of the pleural sacs are approximately the same, but the left sac sometimes descends to a lower level in the midaxillary line.

Fig. 1103.—Structures in relation with the cervical pleura of the right side. Seen from below.

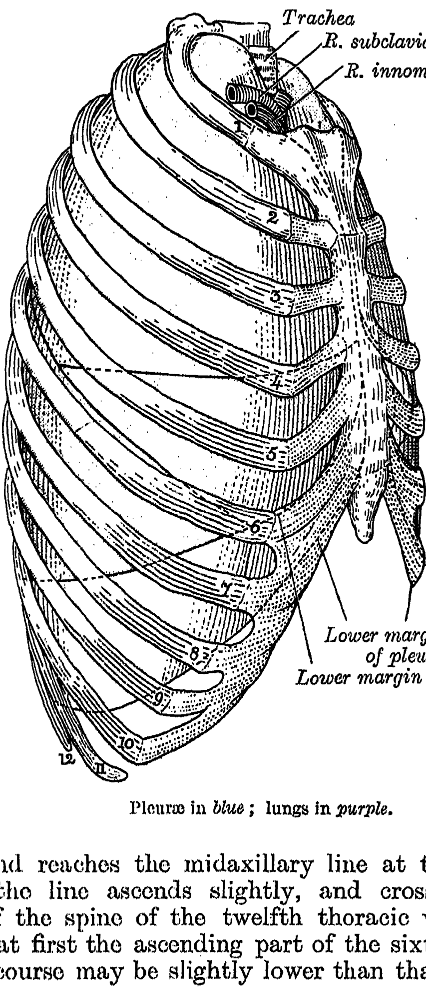


The pulmonary pleura is inseparably connected with the lung. It covers the surfaces of the lung, including those which bound the fissures between the lobes of the lung; it is absent, however, over an area where the lung root enters, and along a line extending downwards from this and marking the attachment of the pulmonary ligament.

The parietal pleura.—Different portions of the parietal pleura have received distinctive names; the part lining the inner surfaces of the ribs and the Subcostales and Intercostales intimi (Intracostales) is the *costal pleura*; that clothing the thoracic surface of the Diaphragm is the *diaphragmatic pleura*; that ascending into the neck over the summit of the lung is the *cervical pleura* (cupula); and that applied to the structures in the middle of the thorax is the *mediastinal pleura*.

The *costal pleura* (figs. 1102, 1104) lines the sternum, ribs, Subcostales and Intercostales intimi, and the sides of the bodies of the vertebræ, and is easily separated from them. In front it begins behind the sternum where it is continuous with the mediastinal pleura. The line of junction of the mediastinal with the costal pleura extends from behind the sternoclavicular joint downwards and medially to a point in the median plane behind the sternal angle. From this point the right and left costal pleuræ descend in contact with each other as far as the level of the fourth costal cartilages, below which the line differs on the two sides. On the right side it is continued down to the posterior surface of the xiphisternal joint. On the left it diverges laterally and descends, close to or a short distance from the margin of the sternum, to the level of the sixth costal cartilage. On each side the costal pleura sweeps laterally, lining the inner surfaces of the costal cartilages, ribs and Intercostales intimi, and at the back of the thorax passes over the sympathetic trunk and its branches, and on to the sides of the bodies of the vertebræ, where it again becomes continuous with the mediastinal pleura. Above, the costal pleura is continuous with the cervical pleura at the inner margin of the first rib. Below, it is continuous with the diaphragmatic pleura along a line which may differ slightly on the two sides. On the right side the line begins behind the xiphoid process, and runs downwards and backwards behind the seventh costal cartilage, and reaches the midaxillary line at the level of the tenth rib; from here the line ascends slightly, and crossing the twelfth rib, reaches the level of the spine of the twelfth thoracic vertebra. On the left side the line follows at first the ascending part of the sixth costal cartilage, and in the rest of its course may be slightly lower than that on the right side.

Fig. 1104.—The relations of the pleuræ and lungs to the chest wall. Lateral aspect.



Pleuræ in *blue*; lungs in *purple*.

The *diaphragmatic pleura* is thin, and covers the upper surface of the corresponding side of the Diaphragm. The outer part of its circumference is the line described above, along which it is continuous with the costal pleura. Medially it is continuous with the mediastinal pleura along the line of attachment of the pericardium to the Diaphragm.

The *cervical pleura* (cupula of the pleura), is the continuation of the costal pleura over the apex of the lung (fig. 1104). It extends from the inner border of the first rib medially and upwards to the apex of the lung, its summit reaching as high as the lower edge of the neck of the first rib; it then descends along the side of the trachea to become continuous with the mediastinal pleura. The cervical pleura is strengthened by a dome-like expansion of fascia, named the *suprapleural membrane* (*Sibson's fascia*). It is attached in front to the inner border of the first rib and behind to the anterior border of the transverse process of the seventh cervical vertebra; it is covered and strengthened by a few spreading muscular fibres derived from the Scaleni. The subclavian artery,

FIG. 1105.—A transverse section through the thorax at the level of the lower part of the fifth thoracic vertebra.

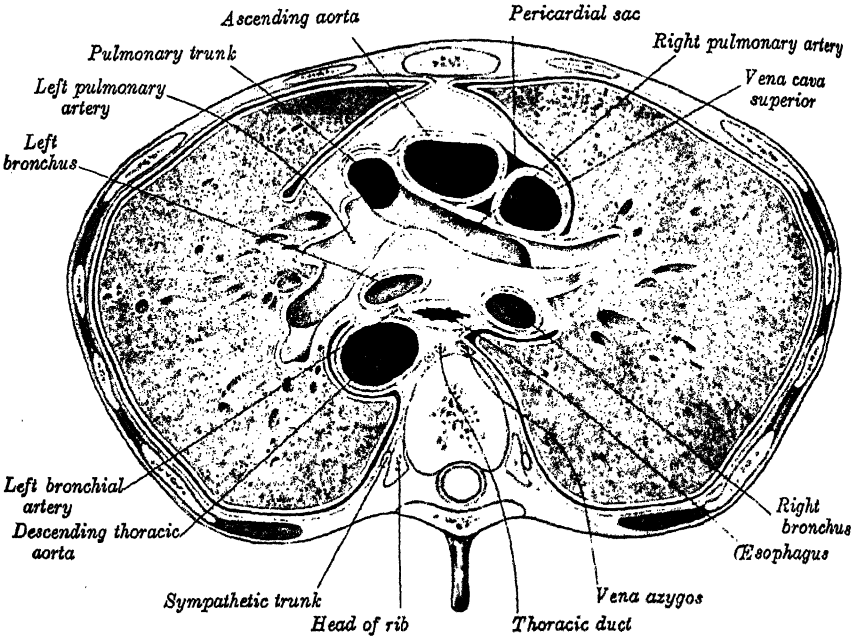
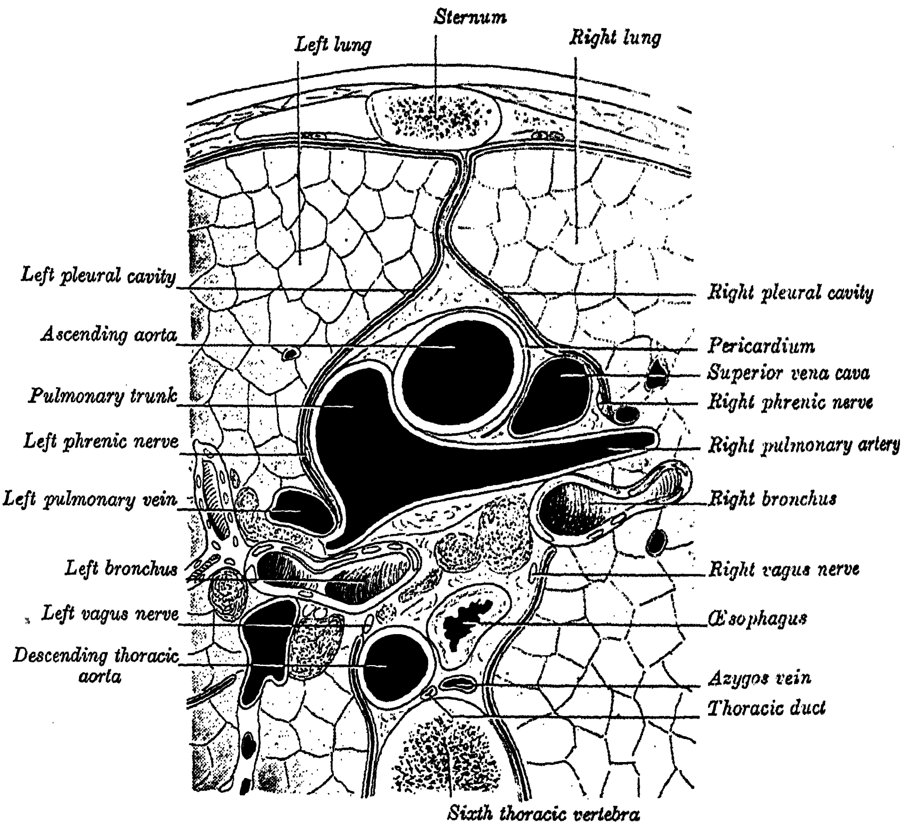


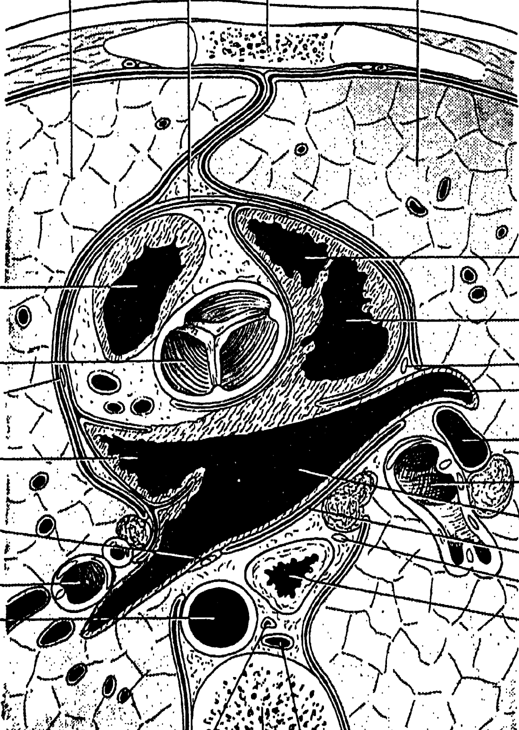
FIG. 1106.—A transverse section through the mediastinum at the level of the upper part of the body of the sixth thoracic vertebra.



directed upwards and laterally, occupies a furrow a little below the summit of the cervical pleura (fig. 1103).

The *mediastinal pleura* forms the lateral boundary of the interpleural space or mediastinum (see also p. 1251). Above the root of the lung it is a continuous sheet between the sternum and the vertebral column. That of the right side is in contact with the right innominate vein, the upper part of the superior vena cava, the terminal part of the azygos vein, the right phrenic and right vagus nerves, the trachea and the œsophagus. That of the left side is in relation with the arch of the aorta, the left phrenic and left vagus nerves, the left innominate and superior intercostal veins, the left common carotid and sub-

FIG. 1107.—A transverse section through the mediastinum at the level of the lower part of the body of the sixth thoracic vertebra.

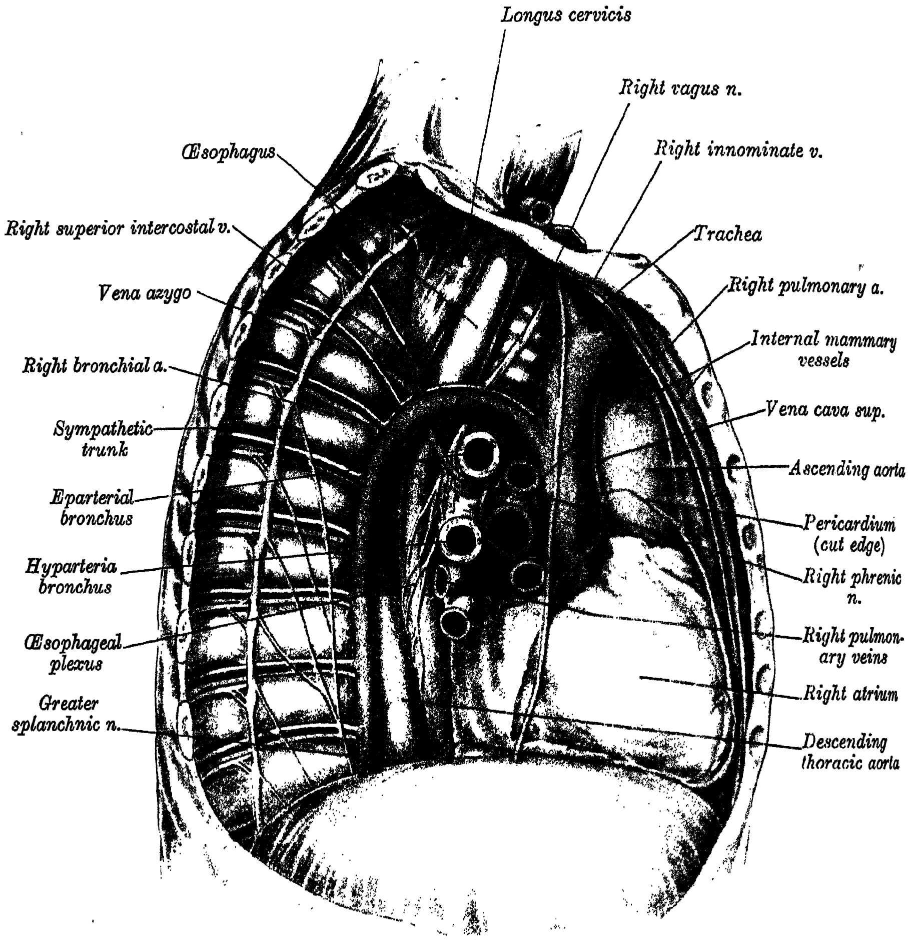


clavian arteries, the thoracic duct and the œsophagus. At the root of the lung the mediastinal pleura is carried laterally as a tube of serous membrane enclosing the structures of the lung-root and passing into continuity with the visceral or pulmonary pleura. Below the lung-root the mediastinal pleura extends as a double layer from the lateral edge of the œsophagus to the mediastinal surface of the lung, where it is continuous with the pulmonary pleura. This double layer is named the *pulmonary ligament* (fig. 1110). It is continuous above with the tube investing the lung-root; below it ends in a free falciform border.

The inferior limit of the pleura is on a considerably lower level than the corresponding border of the lung (figs. 1102, 1104), but does not extend to the attachment of the Diaphragm, so that below the line of reflection of the pleura from the chest-wall to the Diaphragm, the latter is in direct contact with the rib cartilages and the muscles in the intercostal spaces. Moreover, in ordinary

inspiration the thin inferior margin of the lung does not extend as low as the line of the pleural reflection, with the result that the costal and diaphragmatic pleuræ are here in contact, the intervening narrow slit being termed the *costodiaphragmatic recess* (phrenicocostal sinus). A similar condition exists behind the sternum and rib cartilages, where the anterior thin margin of the lung falls short of the line of pleural reflection, and where the slit-like cavity be-

FIG. 1108.—The mediastinum, from the right side.



A portion of the pericardial sac has been removed in order to expose the lateral surface of the right atrium.
In this specimen the fourth right intercostal vein did not join the superior intercostal vein, the œsophagus was somewhat dilated and an unusually large extent of the descending thoracic aorta was visible from the right side.

tween the two layers of pleura forms what is called the *costomediastinal recess* (sinus).

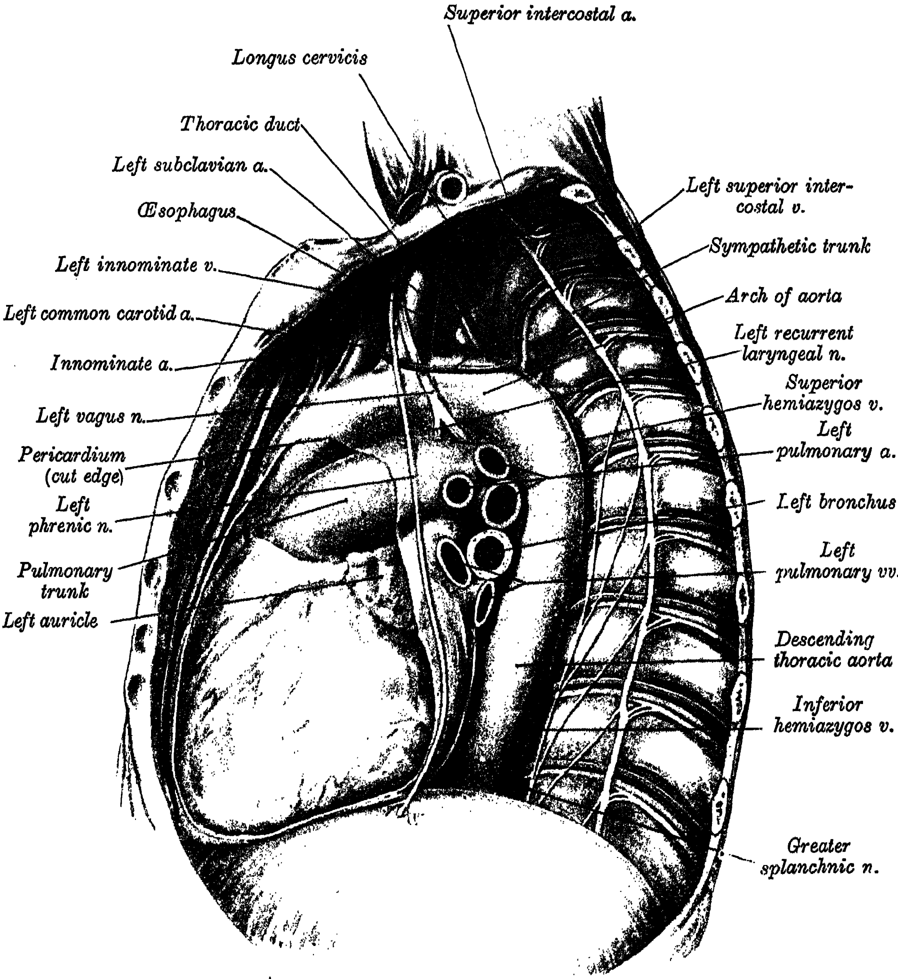
Structure.—The free surface of the pleura is smooth, and moistened by serous fluid. Like other serous membranes, it is covered by a single layer of flattened nucleated cells, united at their edges by cement-substance. These cells form an endothelium, and rest on a basement-membrane. Beneath the basement-membrane there are networks of yellow elastic and white fibres, imbedded in ground-substance which also contains connective tissue cells; in the pulmonary pleura there is a good deal of unstriped muscle. Blood-vessels, lymph vessels and nerves are distributed in the substance of the pleura.

Vessels and Nerves.—The *arteries* of the pleura are derived from the posterior (aortic) intercostal, internal mammary, musculophrenic, thymic, pericardiac and bronchial vessels. The *veins* correspond to the arteries. The *lymph vessels* are described on p. 879. The *nerves* are derived from the phrenic nerve and from the sympathetic trunk. Kölliker

states that nerves accompany the ramifications of the bronchial arteries in the pulmonary pleura.

Applied Anatomy.—Under normal conditions the pulmonary pleura glides smoothly over the surface of the parietal pleura during respiration and causes no sound which can be heard on auscultation, but, when the pleura is inflamed, and prior to, or in the absence of, any effusion of fluid into the pleural cavity, characteristic friction sounds can be

FIG. 1109.—The mediastinum, from the left side.



recognised. When an effusion of fluid occurs into the pleural cavity, the lung gradually collapses and, as the fluid increases in quantity, the heart is displaced towards the opposite side.

When air enters the pleural cavity, either as the result of the rupture of a part of the lung or as the result of its intentional introduction as a therapeutic measure, the elastic tissue of the lung contracts and the organ collapses and may finally shrink away to a dark rounded mass, the size of a closed fist, lying close against the vertebral column. The production of an artificial pneumothorax by the introduction of air into the pleural cavity has been employed in selected cases of pulmonary tuberculosis with the object of giving rest to the diseased lung, and has been attended by a considerable measure of success.

THE MEDIASTINUM

The mediastinum, strictly speaking, is the septum or partition between the two lungs and therefore includes the mediastinal pleura of both sides, but it is much more satisfactory to define it as the interval between the two pleural sacs.

It extends from the sternum in front to the vertebral column behind (figs. 1105, 1106), and from the thoracic inlet above to the Diaphragm below. For purposes of description it is divided into two parts, an *upper*, which is named the superior mediastinum, and a *lower*, which is subdivided into (*a*) the anterior mediastinum, in front of the pericardium, (*b*) the middle mediastinum, occupied by the pericardium and its contents, and (*c*) the posterior mediastinum, behind the pericardium.

The **superior mediastinum** (figs. 1099, 1100) lies between the manubrium sterni in front, and the upper four thoracic vertebræ behind. It is bounded below by a slightly oblique plane passing through the sternal angle in front, and the lower part of the body of the fourth thoracic vertebra behind; above, by the plane of the thoracic inlet, and laterally by the pleuræ. It contains the origins of the Sternohyoid and Sternothyroid and the lower ends of the Longus cervicis (longus colli) muscles; the aortic arch; the innominate, left common carotid and left subclavian arteries; the innominate veins and the upper half of the superior vena cava; the left superior intercostal vein; the vagus, cardiac, phrenic and left recurrent laryngeal nerves; the trachea, œsophagus and thoracic duct; the remains of the thymus, and the paratracheal, innominate and some of the tracheobronchial lymph glands.

The **anterior mediastinum** lies between the body of the sternum in front and the pericardium behind (fig. 1105); above the level of the fourth costal cartilages, it is exceedingly narrow, owing to the close approximation of the two pleural sacs. It contains some loose areolar tissue, the sternopericardiac ligaments, two or three lymph glands and a few small mediastinal branches of the internal mammary artery.

The **middle mediastinum** (figs. 1106, 1107) is the broadest of the subdivisions. It contains the heart enclosed in the pericardium, the ascending aorta, the lower half of the superior vena cava, the terminal part of the azygos vein, the bifurcation of the trachea, the two bronchi, the pulmonary trunk dividing into right and left pulmonary arteries, the right and left pulmonary veins, the phrenic nerves, the deep cardiac plexus and some tracheobronchial lymph glands.

The **posterior mediastinum** (figs. 1105 to 1109) is bounded in front by the bifurcation of the trachea, the pulmonary vessels and the pericardium above, and by the posterior surface of the Diaphragm below; behind, by the vertebral column from the lower border of the fourth to the twelfth thoracic vertebra; and on each side by the mediastinal pleura. It contains the descending thoracic aorta, the azygos and hemiazygos veins, the vagus and splanchnic nerves, the œsophagus, the thoracic duct, and the posterior mediastinal lymph glands.

The Lungs (Pulmones)

The **lungs** are the essential organs of respiration; they are two in number, placed one on each side within the thorax, and separated from each other by the heart and the other contents of the mediastinum (fig. 1110). The substance of the lung is of a light, porous, spongy texture; it floats in water, and crepitates when handled, owing to the presence of air in its alveoli; it is also highly elastic; hence the retracted state of the lungs when they are removed from the closed cavity of the thorax. The surface is smooth, shining, and marked out into numerous polyhedral areas, indicating the lobules of the lung; each of these areas is crossed by numerous lighter lines.

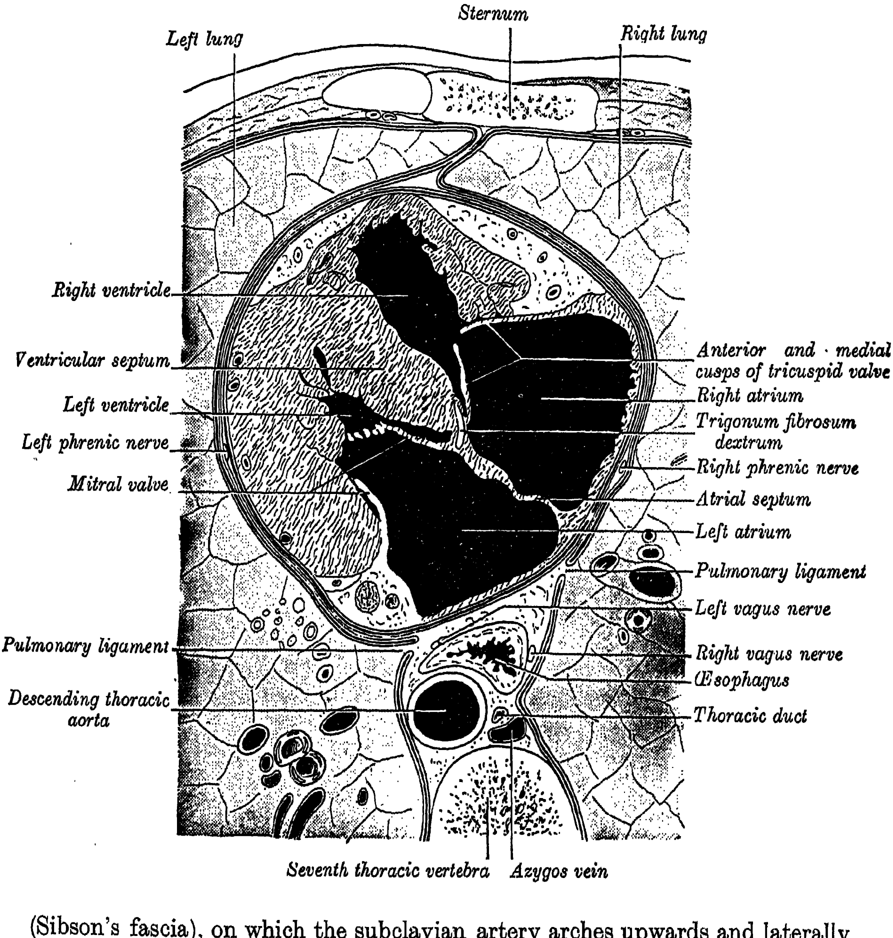
At birth the lungs are pinkish-white in colour; in adult life the colour is a dark slaty-grey, mottled in patches; and as age advances, this mottling assumes a black colour. The colouring matter consists of granules of a carbonaceous substance deposited in the areolar tissue near the surface of the lung; it increases in quantity as age advances, and is more abundant in men than in women. As a rule, the posterior border of the lung is darker than the anterior.

The right lung usually weighs about 625 gm., the left 567 gm., but much variation occurs, and it is dependent on the amount of blood or serous fluid that they contain. The lungs are heavier in the male than in the female; their proportion to the body is, in the former, as 1 to 37, in the latter as 1 to 43.

Each lung is conical in shape, and has an apex, a base, three borders and two surfaces.

The *apex*, which is rounded, lies in the plane of the thoracic inlet, in close contact with the cervical pleura. Owing to the obliquity of the inlet (p. 238), this part of the lung reaches from 3 cm. to 4 cm. above the level of the first costal cartilage, although it does not rise above the level of the neck of the rib. Its summit lies about 2·5 cm. above the medial third of the clavicle, and the apex is situated therefore in the root of the neck (fig. 1102). The cervical pleura intervenes between the apex of the lung and the suprapleural membrane

Fig. 1110.—A transverse section through the mediastinum at the level of the body of the seventh thoracic vertebra.



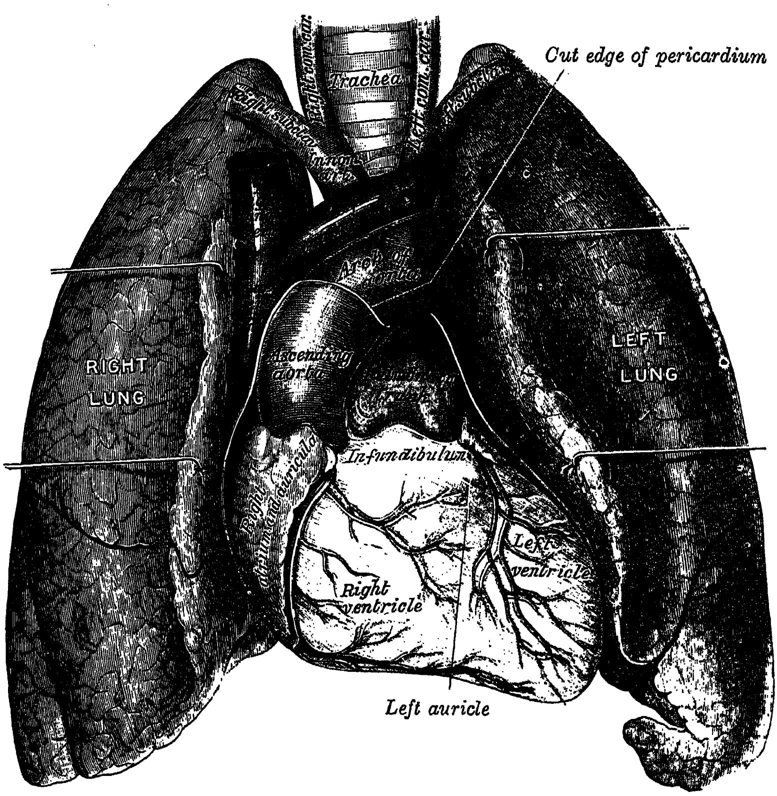
(Sibson's fascia), on which the subclavian artery arches upwards and laterally, producing a groove on the anterior surface of the apex just below its summit and separating it from the Scalenus anterior. Posteriorly the apex is related to the inferior cervical and first thoracic ganglia of the sympathetic trunk, the anterior primary ramus of the first thoracic nerve and the superior intercostal artery (fig. 1103). Laterally, it is related to the Scalenus medius; medially, to the innominate artery, right innominate vein and trachea, on the right side, and to the left subclavian artery and left innominate vein, on the left side.

The *base* is semilunar in shape, and concave; it rests upon the convex surface of the Diaphragm, which separates the right lung from the right lobe of the liver, and the left lung from the left lobe of the liver, the fundus of the stomach and the spleen. Since the Diaphragm extends higher on the right side than on the left, the concavity on the base of the right lung is deeper than that on the left. Laterally and behind, the base is bounded by a thin, sharp margin which projects for some distance into the costodiaphragmatic recess of the pleura.

The *costal surface* is smooth, convex, of considerable extent, and corresponds to the form of the cavity of the chest, which is deeper behind than in front. It is in contact with the costal pleura, and exhibits, in specimens which have been hardened *in situ*, slight grooves corresponding with the overlying ribs. The pleura separates the costal surface of the lung from the ribs, from the constituent parts of the Transversus thoracis muscle (p. 553), and, in places, from the internal mammary vessels and the intercostal nerves and their accompanying vessels and, near the posterior border of the lung, from the sympathetic trunk and the roots of origin of the splanchnic nerves.

The *medial surface* is divided into a posterior or *vertebral* part, and an anterior

Fig. 1111.—The heart and lungs. Anterior aspect.

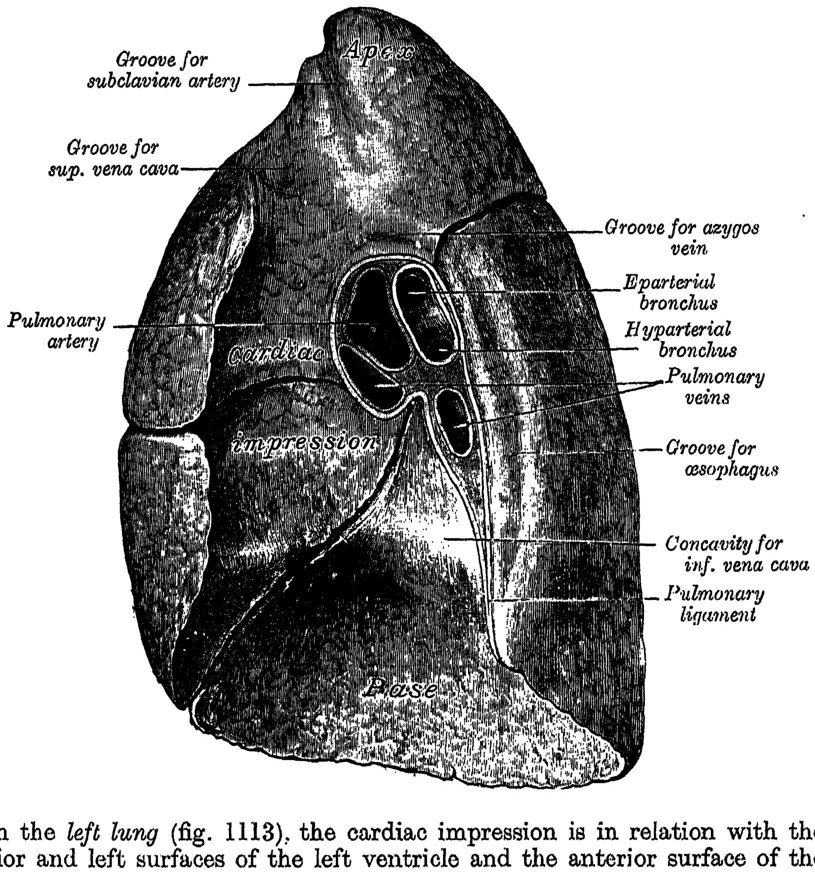


or *mediastinal* part. The vertebral part is in contact with the sides of the thoracic vertebræ and intervertebral discs, the posterior intercostal vessels and the splanchnic nerves. The mediastinal part exhibits a deep concavity, which accommodates the pericardium and is termed the *cardiac impression* ; this concavity is larger and deeper on the left than on the right lung, because the heart projects more to the left than to the right side of the median plane. Above and behind this concavity there is a somewhat triangular depression named the *hilum*, where the structures which form the root of the lung (p. 1257) enter and leave the viscus. These structures are invested by pleura, which extends downwards, below the hilum and behind the cardiac impression, and forms the pulmonary ligament.

Apart from these features, which are shared in common by both lungs, the markings on the mediastinal surface seen in specimens hardened *in situ* are different on the two sides. On the *right lung*, the cardiac impression is in relation with the anterior surface of the right auricle, the anterior and lateral (right) surfaces of the right atrium and a small part of the anterior surface of the right ventricle. It is continued upwards in front of the hilum as a wide groove which lodges the superior vena cava and the lower end of the right innominate

vein (fig. 1112). Posteriorly this groove is joined by a deep, narrow groove which arches forwards above the hilum and is caused by the vena azygos. The right edge of the œsophagus produces a shallow groove which runs vertically downwards behind the hilum and the pulmonary ligament. As it approaches the Diaphragm, the œsophagus inclines towards the left and passes away from the right lung. The œsophageal groove, therefore, does not extend to the lower limit of this surface. The postero-inferior corner of the cardiac impression is confluent with a short but wide notch which accommodates the thoracic part of the inferior vena cava. Between the apex and the groove for the vena azygos, the trachea and the right vagus nerve are in close relation to the lung, although there is no corresponding surface depression.

Fig. 1112.—The medial surface of the right lung.



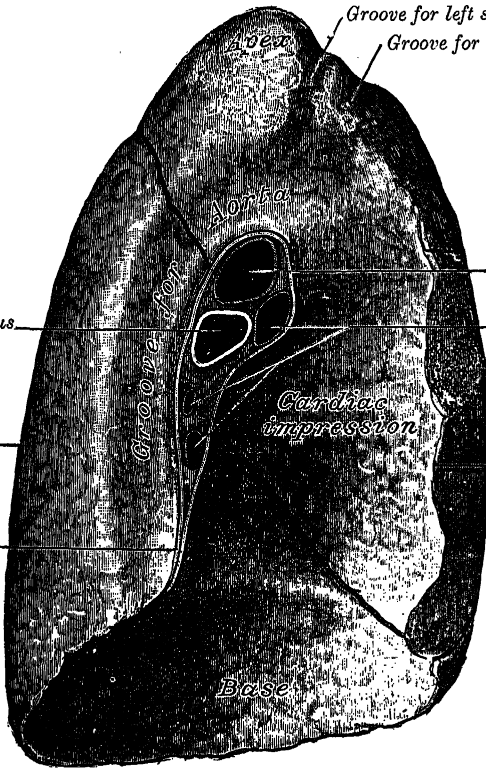
On the *left lung* (fig. 1113), the cardiac impression is in relation with the anterior and left surfaces of the left ventricle and the anterior surface of the infundibulum (conus arteriosus) and adjoining part of the right ventricle. It is continued upwards in front of the hilum to accommodate the pulmonary trunk. A wide, deep groove arches backwards above the hilum and downwards behind it and the pulmonary ligament; it lodges the arch and the descending part of the aorta. Near the summit of its curve it is confluent with a narrower groove which ascends towards the apex and is occupied by the left subclavian artery. Behind this groove and above the aortic groove, the lung is in contact with the thoracic duct and the left edge of the œsophagus. Inferiorly, the left edge of the œsophagus may make a slight impression in front of the lower end of the pulmonary ligament.

The *inferior border* is thin and sharp where it separates the base from the costal surface and extends into the costodiaphragmatic recess; medially, where it divides the base from the mediastinal surface, it is blunt and rounded. The *posterior border* separates the costal surface from the vertebral part of the medial surface, and corresponds to the medial margins of the heads of the ribs. It is not marked by any recognisable ridge or line. The " thick, rounded posterior

border", described in many textbooks, comprises the adjoining parts of the costal and vertebral surfaces.

The *anterior border* is thin and sharp, and overlaps the front of the pericardium ; that of the *right* lung corresponds very closely to the costomediastinal line of pleural reflection and is almost vertical ; that of the *left* corresponds to the costomediastinal line of pleural reflection in its upper part, but below the level of the fourth costal cartilage it presents a notch of variable size, named the *cardiac notch.* The margin of this notch corresponds to, but falls considerably short of, the recessed part of the line of pleural reflection (fig. 1102), leaving the pericardium in this situation covered only with a double layer of pleura.

FIG. 1113.—The medial surface of the left lung.



The fissures and lobes of the lungs.—The *left lung* is divided into a superior and an inferior lobe, by an *oblique fissure* (fig. 1113), which extends from the costal to the medial surface of the lung both above and below the hilum. As seen on the surface, this fissure begins on the medial surface of the lung at the upper and posterior part of the hilum, and runs backwards and upwards to the posterior border, which it crosses at a point about 6 cm. below the apex. It then extends downwards and forwards over the costal surface (fig. 1104), reaching the lower border a little behind its anterior extremity. Its further course can be followed upwards and backwards across the mediastinal surface as far as the lower part of the hilum. The *superior lobe* lies above and in front of this fissure, and includes the apex, the anterior border, a considerable part of the costal surface and the greater part of the medial surface of the lung. A small projection is sometimes present at the lower part of the cardiac notch and is termed the *lingula* of the lung. The *inferior lobe,* the larger of the two, is situated below and behind the fissure, and comprises almost the whole of the base, a large portion of the costal surface, and the greater part of the posterior border.

The *right lung* is divided into three lobes, superior, middle and inferior, by two fissures (fig. 1112). One of these separates the inferior from the middle

and superior lobes, and corresponds closely with the oblique fissure in the left lung. Its direction is, however, more vertical, and it cuts the lower border about 7·5 cm. behind its anterior extremity. A short *transverse fissure* separates the superior from the middle lobe. It begins in the oblique fissure near the mid-axillary line, and, running horizontally forwards, cuts the anterior border on a level with the sternal end of the fourth costal cartilage ; on the mediastinal surface it may be traced backwards to the hilum. The *middle lobe* of the right lung is small and wedge-shaped, and includes a part of the costal surface, the lower part of the anterior border and the anterior part of the base of the lung. Sometimes the right lung is deeply cleft near its apex by a fold of pleura which contains the azygos vein in its free margin.

Since the Diaphragm rises higher on the right side in order to accommodate the liver, the right lung is shorter (by 2·5 cm.) than the left, but, owing to the projection of the heart to the left side, it is broader and its total capacity and weight are greater than those of the left lung.

The roots of the lungs (figs. 1108, 1109).—The root of the lung connects the medial surface to the heart and the trachea and is formed by the structures which enter or emerge at the hilum. It comprises the bronchus, the pulmonary artery, the two pulmonary veins, the bronchial arteries and veins, the pulmonary plexuses of nerves, lymph vessels, bronchopulmonary lymph glands and areolar tissue, all of which are enveloped by pleura. The roots of the lungs lie opposite the bodies of the fifth, sixth and seventh thoracic vertebræ. That of the right lung lies behind the superior vena cava and part of the right atrium of the heart, and below the terminal part of the azygos vein. That of the left lung is below the aortic arch and in front of the descending thoracic aorta. The following relations are common to the two lung-roots, viz. : in front, the phrenic nerve, the pericardiacophrenic artery and vein, and the anterior pulmonary plexus ; behind, the vagus nerve and posterior pulmonary plexus ; below, the pulmonary ligament.

The chief structures composing the root of each lung are arranged in a similar manner from before backwards on both sides, viz. : the upper of the two pulmonary veins in front ; the pulmonary artery in the middle ; and the bronchus behind, with the bronchial vessels on its posterior aspect. Their arrangement differs from above downwards on the two sides ; on the right side their position is—eparterial bronchus, pulmonary artery, hyparterial bronchus, lower pulmonary vein ; but on the left side their position is—pulmonary artery, bronchus, lower pulmonary vein. The lower of the two pulmonary veins is situated below the bronchus, at the lowest part of the hilum.

The divisions of the bronchi.—Just as the lungs differ from each other in the number of their lobes, so the bronchi differ in their mode of subdivision.

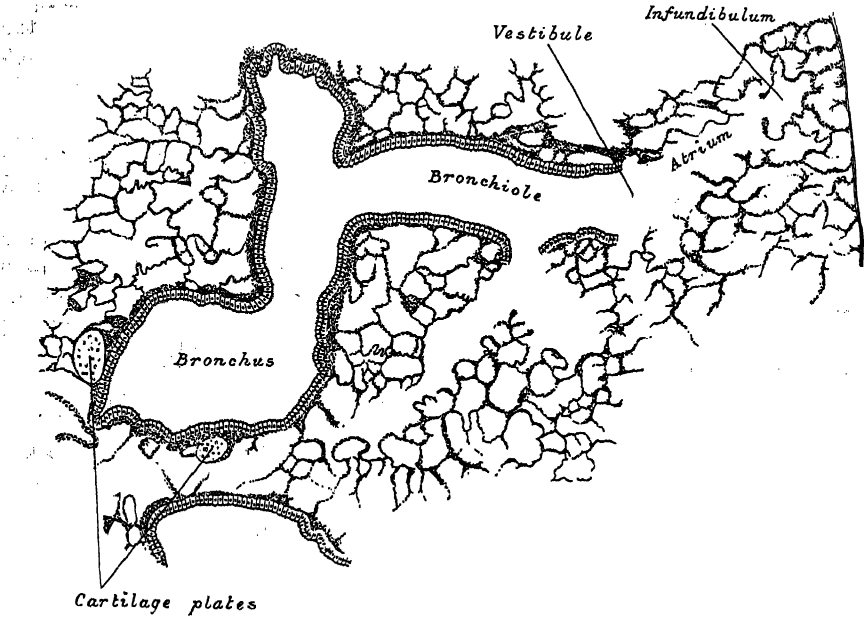
The *right* bronchus gives off, less than 2·5 cm. from the division of the trachea, a branch for the superior lobe ; this branch arises above the level of the pulmonary artery, and is therefore named the *eparterial bronchus*. All the other divisions of the main stem come off below the pulmonary artery, and are consequently termed *hyparterial bronchi*. The first of these is distributed to the middle lobe, and the main tube then passes downwards and backwards into the inferior lobe, giving off in its course a series of large ventral and small dorsal branches. The ventral and dorsal branches arise alternately, and there are usually four of each. The branch to the middle lobe is the first of the ventral series ; the first of the dorsal branches is the largest and is distributed to the upper part of the inferior lobe.

The *left* bronchus passes below the level of the pulmonary artery before it divides, and hence all its branches are hyparterial ; it may therefore be looked upon as equivalent to that portion of the right bronchus which lies on the distal side of its eparterial branch. The first branch of the left bronchus arises about 5 cm. from the bifurcation of the trachea, and is distributed to the superior lobe. The main stem then enters the inferior lobe, where it divides into ventral and dorsal branches similar to those in the right lung. The branch to the superior lobe of the left lung is the first of the ventral series, and the second is distributed to the portion of the upper lobe which corresponds to the middle lobe of the right lung.

Structure.—The lungs are composed of a serous coat, a subserous areolar tissue, and the pulmonary substance.

The *serous* coat is the pulmonary pleura (p. 1246); it is thin, transparent, and invests the entire organ as far as the root.

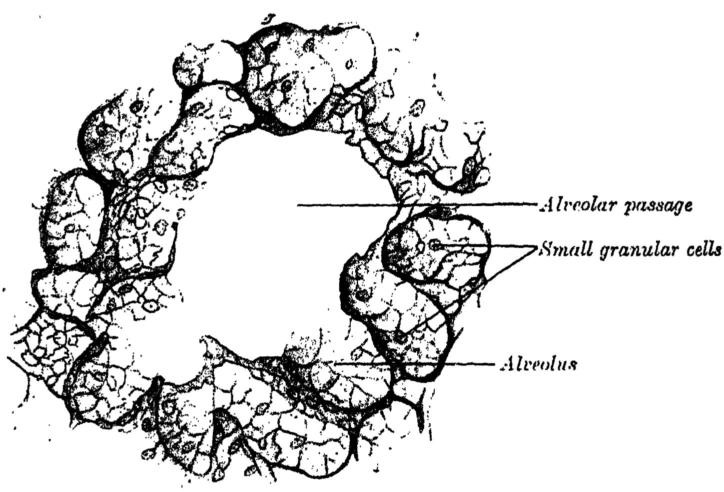
FIG. 1114.—A section through the lung of a cat, showing the termination of a bronchus. × 50.



The *subserous areolar tissue* contains a large proportion of elastic fibres; it invests the entire surface of the lung and extends inwards between the lobules.

The *pulmonary substance* is composed of lobules, which although closely connected by interlobular areolar tissue, are quite distinct from one another, and in the fœtus may be

FIG. 1115.—A section through the lung of a kitten. Silver preparation. × 250.

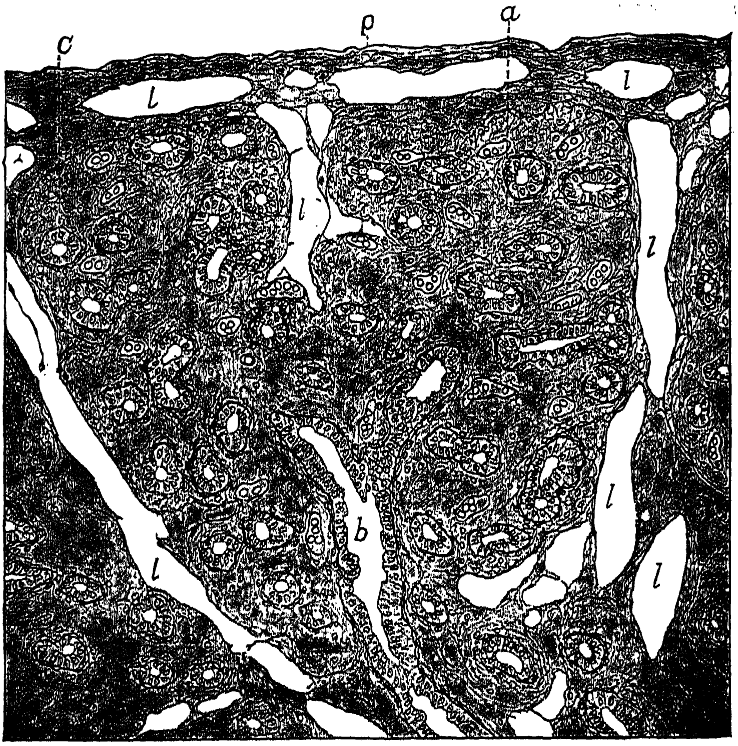


teased apart without much difficulty. The lobules vary in size; those on the surface are large and of pyramidal form with the bases turned towards the surface; those in the interior are smaller, and of various forms. Each lobule is composed of a terminal bronchiole and its air-cells, and of the ramifications of the pulmonary and bronchial vessels, lymph vessels, and nerves; all of these structures being connected together by areolar tissue.

The **intrapulmonary bronchi** divide and subdivide throughout the entire organ, the smallest branches constituting the terminal bronchioles. The *larger branches* consist of: (1) an outer coat of fibrous tissue in which are found at intervals irregular plates of hyaline cartilage, most developed at the points of division; (2) internal to the fibrous coat, a layer of circularly disposed smooth muscular fibres, termed the *bronchial muscle*; and (3) most internally, the mucous membrane, lined by ciliated columnar epithelium resting on a basement-membrane. The mucous membrane contains numerous elastic fibres running longitudinally, and a certain amount of lymphoid tissue; it is traversed by the ducts of mucous glands, the acini of which lie in the fibrous coat. The *terminal bronchioles* are about 0·2 mm. in diameter; they differ from the larger tubes in containing no cartilage and in the fact that the ciliated epithelial cells are cubical in shape.

Each bronchiole ends by opening into a wider space known as the *vestibule*, the point of junction of the two being marked by a circular thickening of the bronchial muscle, and

FIG. 1116.—A section through the lung of a pig-embryo 13 cm. long, showing the glandular character of the developing alveoli. ×70. (J. M. Flint.)



a. Interstitial connective tissue. *b.* A bronchial tube. *c.* An alveolus. *l.* Lymphatic clefts. *p.* Pleura.

by a transition from the ciliated epithelium of the bronchiole to a layer of flattened non-ciliated cells. The vestibule divides into from three to six passages called *atria*. These are lined with flattened non-ciliated epithelium. From each atrium there arise two or more *infundibula*—elongated passages, lined by pavement epithelium and beset on all sides by hemispherical alveoli or air-cells (fig. 1114).

The *alveoli* are lined by a layer of simple flattened epithelium, the cells of which are united at their edges by cement-substance. Between these cells, here and there, smaller polygonal nucleated cells are found. Outside the epithelial lining there is a little delicate connective tissue, containing numerous elastic fibres and a close network of blood-capillaries, and forming a common wall to adjacent alveoli (fig. 1115).

The fœtal lung resembles a gland in that the alveoli have small lumina and are lined with cubical epithelium (fig. 1116). After the first respiration the alveoli become distended, and the epithelium takes on the characters described above.

Vessels and Nerves.—The *pulmonary artery* conveys the deoxygenated blood to the lungs; it divides into branches which accompany the bronchial tubes and lie close to their dorsal aspects. They end in a dense capillary network in the walls of the infundibula and alveoli. The arteries of neighbouring lobules are independent of one another.

The *pulmonary capillaries* form plexuses which lie immediately beneath the lining epithelium, in the walls and septa of the alveoli and of the infundibula. In the septa

between the alveoli the capillary network forms a single layer, the meshes of which are smaller than the vessels themselves; their walls are also exceedingly thin.

The *pulmonary veins*, two from each lung, arise from the pulmonary capillaries, the radicles coalescing into larger branches which run through the substance of the lung, independently of the pulmonary arteries and bronchi. After communicating freely with other branches they form large vessels, which ultimately come into relation with the arteries and bronchial tubes, and accompany them to the hilum of the lung, the artery usually being above, and the vein below, the bronchus. Finally, they open into the left atrium of the heart, conveying oxygenated blood to be distributed to all parts of the body by the left ventricle.

The *bronchial arteries* supply blood for the nutrition of the lung; they are derived from the descending thoracic aorta or from the upper posterior (aortic) intercostal arteries, and, accompanying the bronchial tubes, are distributed to the bronchial glands and upon the walls of the larger bronchial tubes and pulmonary vessels. Those supplying the bronchial tubes form, in the muscular coat, a capillary plexus from which branches are given off to form a second plexus in the mucous coat; this plexus communicates with branches of the pulmonary artery, and empties itself into the pulmonary veins. Others are distributed in the interlobular areolar tissue, and end partly in the deep, partly in the superficial, bronchial veins. Lastly, some ramify upon the surface of the lung, beneath the pleura, where they form a capillary network.

The *bronchial veins*, usually two on each side, are formed at the root of the lung, and receive superficial and deep veins corresponding with branches of the bronchial arteries; they do not, however, receive all the blood conveyed by the arteries, as some passes into the pulmonary veins. The right bronchial veins end in the azygos vein, the left bronchial veins in the left superior intercostal vein or the superior (accessory) hemiazygos vein.

The *lymph vessels* of the lungs are described on p. 878.

Nerves.—The lungs are supplied from the anterior and posterior pulmonary plexuses, formed chiefly by branches from the sympathetic and vagus. The filaments from these plexuses accompany the bronchial tubes, supplying efferent fibres to the bronchial muscle and afferent fibres to the bronchial mucous membrane and to the alveoli of the lung. Small ganglia are found upon these nerves. It is generally believed that the broncho-constrictors are supplied by the vagus.

Applied Anatomy.—The routine methods of physical examination—inspection, palpation, percussion and auscultation—are nowhere more important than they are in the diagnosis of disease of the lungs, It is essential, too, that in every case the two sides of the chest should be compared with each other, and that the wide variations that may be met with under normal conditions in different persons and at different ages should be kept in mind when the chest is being examined. On *inspection* the thorax will be seen to be enlarged and barrel-shaped in emphysema, in which the volume of the lungs is increased by dilatations of their alveoli, or in an acute attack of asthma, or when a large pleural effusion or mediastinal tumour is present. The chest-wall will be flattened or sunken, on the other hand, over an area of lung that has collapsed or become fibrosed, as often happens in chronic pulmonary tuberculosis. The respiratory movements of the chest-wall will be lessened, or even absent, over a part or the whole of the affected side in such acute disorders as pleurisy, pneumonia, or pleural effusion, or in more chronic disease where the underlying lung is fibrosed, or is crushed to one side by a mediastinal tumour: and by the use of the x-rays a corresponding loss of movement or displacement of the Diaphragm on the affected side can often be observed. Under normal conditions the intercostal spaces are a little depressed: but when a large effusion or new growth fills up one of the pleural cavities they may be obliterated or even bulging on that side.

On *palpation* the hand can be used to verify the eye's impression as to the degree of movement, on respiration, of any part of the chest-wall. The facility with which the vibrations produced by the voice are conducted from the larynx to the hand by the underlying lung (in the form of the *vocal fremitus*) can also be tested. The vocal fremitus is commonly much increased over the consolidated area in pneumonia or in fibrosis of the lung, and much diminished over a pleural effusion when the lung is pushed up by the fluid towards the top of the pleural cavity. It is also diminished, but to a less extent, in emphysema, and in bronchitis when the bronchi are blocked by secretion. It must be remembered that vocal fremitus in front and behind is normally greater at the right apex than the left. This is because the apex of the right lung lies in close contact with the trachea, while the apex of the left lung is separated from it by the œsophagus and other structures.

On *percussion*, the normal resonance of the pulmonary tissue is found to be increased in emphysema, and in pneumothorax (p. 1251) this hyper-resonance may be increased still further. The resonance is lessened in any condition causing collapse or solidification of the lung-tissue, or when its place is taken by fluid (pleural effusion) or some solid growth (mediastinal tumour).

On *auscultation* of the lungs, both in health and disease, the variety of sounds to be heard is very great. It is impossible to give adequate consideration to them here, and for further information reference should be made to the text-books dealing with the subject.

THE DIGESTIVE SYSTEM

The digestive system comprises all the organs which are concerned in the trituration, deglutition and digestion of food and in the elimination from the body of the unabsorbed and unabsorbable constituents. It consists of the digestive tube and certain accessory organs.

The **digestive tube** (alimentary canal), about 9 metres long, extends from the mouth to the anus, and is lined throughout by mucous membrane. It consists of the following parts : it commences at the *mouth*, where provision is made for the mechanical division of the food [*mastication*], and for its admixture with a fluid secreted by the salivary glands [*insalivation*] ; it is conveyed by the organs of deglutition, termed the *pharynx* and the *œsophagus*, into the *stomach*, where the first stages of the digestive process take place ; from the stomach it is passed into the *small intestine*, where the process of digestion is continued and many of the resulting products are absorbed into the blood- and lymph-vessels. Finally the small intestine ends in the *large intestine*, which reaches the surface of the body at the *anus*.

The **accessory organs** are the *teeth*, which break up and triturate the food in the process of mastication ; the three pairs of *salivary glands*—the *parotid*, *submandibular* (submaxillary) and *sublingual*—the secretion from which mixes with the food in the mouth ; the *liver* and the *pancreas*, two large glands in the abdomen, the secretions of which take part in the process of digestion. In addition, it is convenient to describe the *peritoneum*—a serous membrane which lines the abdominal and pelvic cavities and invests the abdominal and pelvic viscera—in the same section with the abdominal part of the alimentary canal.

The Mouth Cavity [Cavum oris]

The **cavity of the mouth** is placed at the commencement of the digestive tube (fig. 1117) ; it consists of an outer, smaller portion, termed the vestibule, and an inner, larger part, termed the mouth cavity proper.

The *vestibule of the mouth* is a slit-like space, bounded externally by the lips and cheeks ; internally, by the gums and teeth. It communicates with the exterior by the *oral fissure*. Above and below, it is limited by the reflection of the mucous membrane from the lips and cheeks to the gums. When the jaws are closed it communicates with the mouth cavity proper by an aperture behind the wisdom tooth on each side, and by narrow clefts between opposing teeth. On the oral surface of the cheek, opposite the second upper molar tooth, a small papilla marks the opening of the duct of the parotid salivary gland.

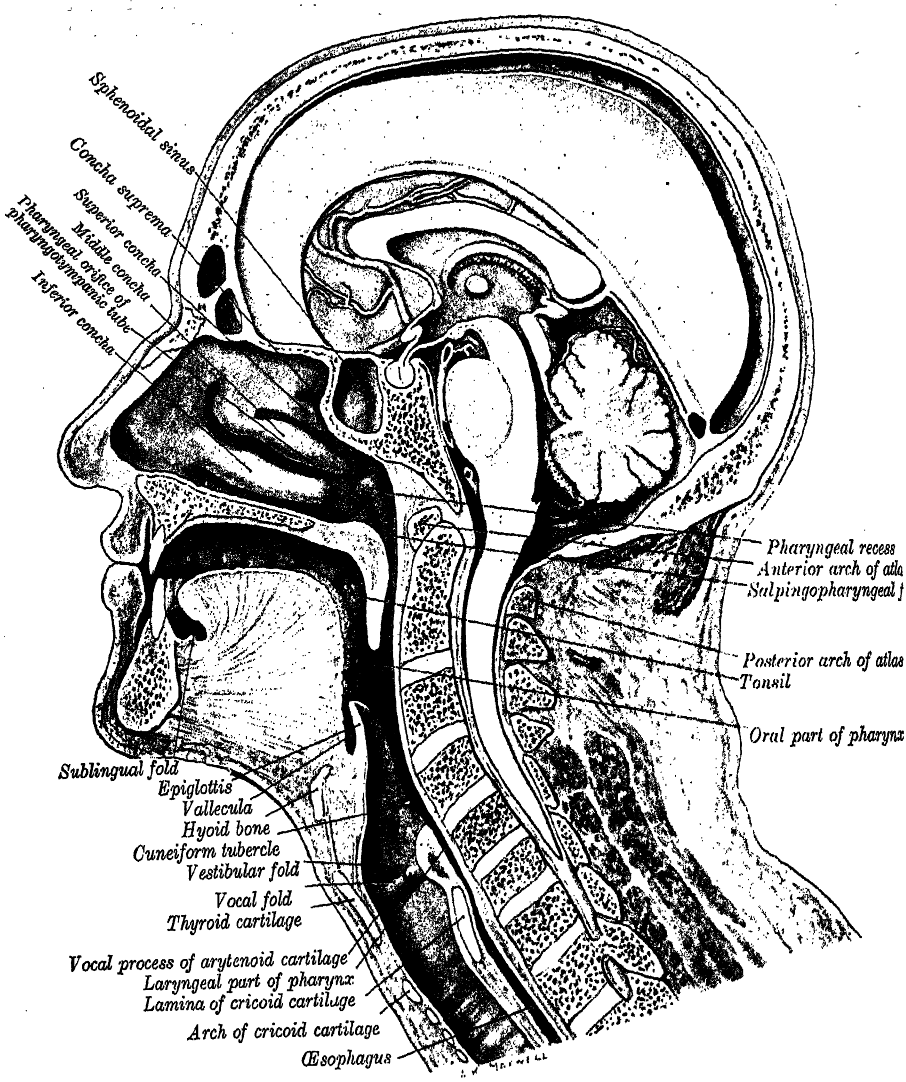
The *mouth cavity proper* (figs. 1141, 1142) is bounded laterally and in front by the alveolar arches, the teeth and the gums ; behind, it communicates with the pharynx by a constricted aperture termed the *oropharyngeal isthmus* (isthmus of the fauces *). Its roof consists of the hard palate and soft palate, while the greater part of the floor is formed by the anterior two-thirds of the tongue, the remainder by the reflection of the mucous membrane from the sides and under surface of the tongue to the gum on the inner surface of the mandible. In the median plane a crescentic fold of mucous membrane, named the *frenulum linguæ*, connects the under surface of the anterior part of the tongue to the floor of the mouth. On each side of the lower end of the frenulum there is a small elevation,

* These two terms are not quite synonymous, as the oropharyngeal isthmus is restricted to the interval between the palatoglossal arches.

termed the *sublingual papilla*, which bears on its surface the orifice of the duct of the submandibular salivary gland. From this papilla a ridge extends laterally and backwards in the mucous membrane of the floor of the mouth; it is produced by the underlying sublingual salivary gland and is termed the *sublingual fold*. The minute openings of the ducts of the gland are situated on the edge of the fold.

The *mucous membrane* lining the mouth is continuous with the skin at the free margins of the lips, and with the mucous lining of the pharynx at the oropharyngeal isthmus; it is

FIG. 1117.—A median sagittal section through the head and neck.



Note.—Where it divides the skull and the brain, the section passes slightly to the left of the median plane, but below that level, it passes slightly to the right of the median plane.

of a rose pink tinge during life, and is very thick where it overlies the hard parts bounding the cavity. It is covered with stratified squamous epithelium.

The *lymph vessels* of the mouth are described on p. 855.

The lips are two fleshy folds which surround the orifice of the mouth. They are formed externally of skin and internally of mucous membrane, and these two layers enclose the Orbicularis oris muscle, the labial vessels, some

nerves, areolar tissue, and numerous small labial glands. The junction of the upper with the lower lip forms, on each side, the *labial commissure*, which bounds the *angle of the mouth*. The middle part of the outer surface of the upper lip is marked by a shallow vertical groove named the *philtrum*; it ends below in a slight prominence and is limited on each side by a ridge. The inner surface of each lip is connected in the median plane to the corresponding gum by a fold of mucous membrane, termed the *frenulum*—that of the upper lip being the larger.

The *labial glands* are situated between the mucous membrane and the Orbicularis oris, round the orifice of the mouth. They are about the size of small peas and in structure they resemble the salivary glands. Their ducts open into the vestibule.

The **cheeks** form a large part of the sides of the face, and are continuous in front with the lips, the junction being indicated on each side by a groove, termed the *nasolabial groove*, which runs downwards and laterally from the side of the nose to the angle of the mouth. The cheeks are composed of a muscular stratum, and a large quantity of fat, together with areolar tissue, vessels, nerves and buccal glands, covered with skin, externally, and with mucous membrane, internally.

The *mucous membrane* lining the cheek is reflected above and below on to the gums, and is continuous behind with the mucous membrane of the soft palate. Opposite the second upper molar tooth there is a small papilla, on the summit of which the parotid duct opens. The principal muscle of the cheek is the Buccinator; but others enter into its formation, viz. the Zygomaticus major, Risorius and Platysma.

The *buccal glands* are placed between the mucous membrane and the Buccinator muscle; their structure is similar to that of the labial glands. Four or five, larger than the rest, and placed between the Masseter and Buccinator muscles around the terminal part of the parotid duct, are called *molar glands*; their ducts open in the mouth opposite the last molar tooth.

The *lymph vessels* of the cheeks and lips are described on p. 853.

The **gums** are composed of dense, fibrous tissue, closely connected to the periosteum of the alveolar processes of the mandible and maxillæ, and covered with smooth and vascular mucous membrane. Around the necks of the teeth this membrane presents numerous fine papillæ, and is reflected into the alveoli, where it is continuous with their lining periosteal membrane.

The **palate** forms the roof of the mouth: it consists of two portions—the hard palate in front, the soft palate behind.

The **hard palate** (fig. 1127) is formed by the palatine processes of the maxillæ and the horizontal plates of the palatine bones; it is bounded in front and at the sides by the alveolar arches and gums; behind, it is continuous with the soft palate. It is covered with a dense tissue, formed by the periosteum and mucous membrane, which are intimately connected. It presents a median, linear raphe, which ends anteriorly in a small papilla underlying the incisive fossa. On each side and in front of the raphe the mucous membrane is thick, pale in colour, and corrugated; behind, it is thin, smooth, and of a redder colour: it is covered with stratified squamous epithelium, and furnished with numerous palatine glands, which lie between the mucous membrane and the periosteum.

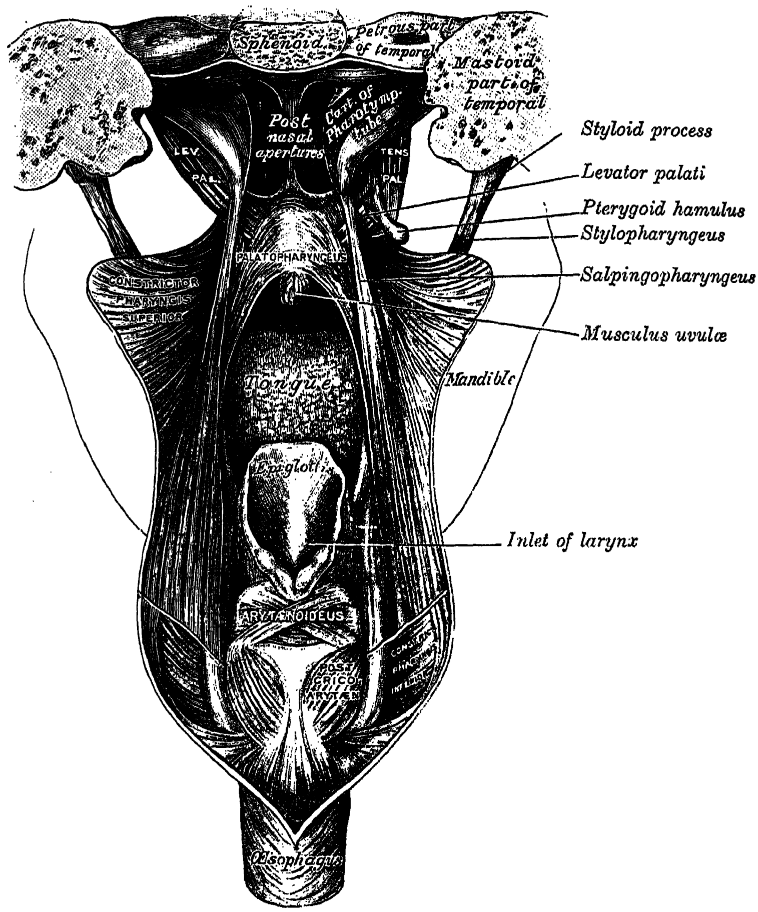
The **soft palate** (fig. 1142) is a movable fold, suspended from the posterior border of the hard palate, and forming an incomplete septum between the mouth and pharynx. It consists of a fold of mucous membrane enclosing an aponeurosis, muscular fibres, vessels, nerves, adenoid tissue and mucous glands. When occupying its usual position (i.e. relaxed and pendent) its anterior surface is concave, and marked by a median raphe. Its posterior surface is convex, and continuous with the floor of the nasal cavity. Its superior border is attached to the posterior margin of the hard palate, and its sides are blended with the pharynx. Its inferior border is free. The lower portion of the soft palate hangs like a curtain between the mouth and the pharynx.

A small conical process, termed the *uvula*, hangs from the middle of its lower border; and two curved folds of mucous membrane, containing muscular fibres, extend laterally and downwards from each side of the base of the uvula. The anterior of the two contains the Palatoglossus (Glossopalatinus) muscle

and is named the *palatoglossal arch*. Below, it reaches the side of the tongue at the junction of the oral and pharyngeal portions and it forms the lateral boundary of the oropharyngeal isthmus. The posterior fold, which is termed the *palatopharyngeal arch*, descends on the lateral wall of the oral part of the pharynx and is described on p. 1292.

The *mucous membrane of the soft palate* is thin, and covered with stratified squamous epithelium excepting near the pharyngeal orifice of the pharyngotympanic (auditory) tube and on the anterior part of its superior surface, where it is columnar and ciliated. Beneath

FIG. 1118.—The muscles of the palate. Exposed from behind.



the mucous membrane on the oral surface of the soft palate there is a considerable amount of adenoid tissue. The palatine glands form a continuous layer on its posterior surface and round the uvula.

Vessels and Nerves.—The *arteries* supplying the palate are the ascending palatine branch of the facial (external maxillary) artery, the greater palatine branch of the (internal) maxillary artery, and the palatine branch of the ascending pharyngeal artery. The *veins* end chiefly in the pterygoid and tonsillar plexuses. The *lymph vessels* pass to the deep cervical lymph glands. The *sensory nerves* are derived from the greater and lesser palatine, long sphenopalatine and glossopharyngeal nerves.

The palatine aponeurosis.—A thin, firm fibrous lamella, termed the *palatine aponeurosis*, which supports the muscles and gives strength to the soft palate, is attached to the posterior border of the hard palate. It is thick above, but very thin and difficult to define below. On each side it is continuous with the

tendon of the Tensor palati and, near the median plane, it splits to enclose the Musculus uvulæ.

Blakeway * maintains that the palatine aponeurosis is not a separate structure, but is actually the expanded tendon of the Tensor palati.

The **muscles of the palate** (fig. 1118) are:

Levator palati.	Palatoglossus.
Tensor palati.	Palatopharyngeus.
Musculus uvulæ.	

The **Levator palati** (Levator veli palatini) (figs. 1118, 1146, 1150) is a rounded muscle situated on the lateral side of the posterior nasal aperture. It arises from the under surface of the petrous part of the temporal bone, immediately in front of the lower opening of the carotid canal, and from the medial lamina of the cartilage of the pharyngotympanic (auditory) tube. After passing within the upper concave margin of the Superior constrictor and in front of the Salpingopharyngeus, it spreads out in the soft palate, its fibres running as far as the median plane, where they blend with those of the opposite muscle. It is separated from the mucous membrane on the posterior (upper) aspect of the soft palate by the posterior (upper) part of the Palatopharyngeus.

Action.—The Levator palati elevates the soft palate.

The **Tensor palati** (Tensor veli palatini) (figs. 1118, 1146, 1150) is a thin, triangular muscle, which lies lateral to the medial pterygoid plate, the pharyngotympanic tube and the Levator palati. Its lateral surface is in contact with the upper and anterior part of the Medial Pterygoid muscle, the mandibular nerve, the otic ganglion and the middle meningeal artery. It arises from the scaphoid fossa of the pterygoid process, the lateral lamina of the cartilage of the pharyngotympanic tube and the medial aspect of the spine of the sphenoid bone. As it descends, its fibres converge to form a delicate tendon which turns medially round the pterygoid hamulus, and is inserted into the palatine aponeurosis and into the surface behind the palatine crest on the horizontal plate of the palatine bone. Between the tendon and the pterygoid hamulus there is a small bursa.

Actions.—Acting singly the Tensor palati pulls the soft palate to one side; acting together the two muscles tighten the soft palate and depress it by flattening out its arch.

The **Musculus uvulæ** arises from the posterior nasal spine of the palatine bones and from the palatine aponeurosis; it descends to be inserted into the uvula.

Action.—The Musculus uvulæ pulls up the uvula on its own side.

The **Palatoglossus** (Glossopalatinus) is a small, fleshy fasciculus, narrower in the middle than at the ends, forming, with the mucous membrane covering its surface, the palatoglossal arch. It arises from the anterior surface of the soft palate, where it is continuous with the muscle of the opposite side, and passing downwards, forwards and laterally in front of the tonsil, is inserted into the side of the tongue, some of its fibres spreading over the dorsum of the tongue, and others passing deeply into its substance to intermingle with the Transversus linguæ.

Actions.—The Palatoglossus pulls up the root of the tongue and approximates the palatoglossal arch to the median plane.

The **Palatopharyngeus** (Pharyngopalatinus) (figs. 1118, 1150) forms, with the mucous membrane covering its surface, the palatopharyngeal arch. In the palate it consists of two layers, which are separated by the Levator palati. The *posterior* (or *upper*) *layer* is in contact with the mucous membrane covering the posterior surface of the palate; it joins with the posterior layer of the opposite muscle in the median plane. The *anterior* (or *lower*) *layer*, the thicker, lies between the Levator and the Tensor palati muscles. It arises from the posterior border of the hard palate and from the palatine aponeurosis, while some of its fibres join in the median plane with the corresponding layer of the opposite muscle. At the posterolateral border of the palate the two

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layers of the muscle unite and are joined by the fibres of the Salpingopharyngeus muscle (p. 1298). Passing laterally and downwards behind the tonsil, the Palatopharyngeus descends posteromedial to, and in close contact with, the Stylopharyngeus, and is inserted with it into the posterior border of the thyroid cartilage, some of its fibres ending on the side of the pharynx, and others passing across the median plane posteriorly, to decussate with those of the opposite muscle. The Palatopharyngeus really forms an internal longitudinal muscular coat for the pharynx.

Actions.—The Palatopharyngeus pulls the walls of the pharynx, on its own side, upwards, forwards and medially, and so shortens the pharynx during the act of swallowing. Acting together the two muscles approximate the palatopharyngeal arches and draw them forwards.

Nerve-supply.—With the exception of the Tensor palati, which is innervated by the mandibular nerve through the otic ganglion, all the muscles of the soft palate are supplied by the accessory nerve through the pharyngeal plexus.

When the soft palate is dissected from its posterior, or pharyngeal, to its anterior, or oral, surface, the muscles are exposed in the following order: (1) the posterior fasciculus of the Palatopharyngeus, covered posteriorly with a continuation of the nasal mucous membrane; (2) the Musculus uvulæ, enclosed in the palatine aponeurosis; (3) the Levator palati; (4) the anterior fasciculus of the Palatopharyngeus; (5) the aponeurosis of the Tensor palati; and (6) the Palatoglossus, covered anteriorly with a continuation of the oral mucous membrane.

The *movements of the soft palate* are described on p. 1298.

Applied Anatomy.—The occurrence of a congenital cleft in the palate has been already referred to as a defect in development (p. 96). Paralysis of the soft palate often occurs after diphtheria. It gives rise to a change in the voice, which becomes nasal, and to the regurgitation of fluids into the nose when swallowing is attempted. On inspection, the palate is seen to hang flaccid and motionless when phonation or deglutition is attempted; it is also anæsthetic.

The Salivary Glands (fig. 1122)

Three pairs of salivary glands pour their secretion into the mouth: they are named the parotid, the submandibular (submaxillary) and the sublingual glands.

The **parotid gland** (figs. 1119, 1120), the largest of the three, has an average weight of about 25 gm. It forms an irregular, lobulated mass, lying below the external auditory meatus, between the mandible and the Sternomastoid; it projects forwards on to the surface of the Masseter, where a small part of it, usually more or less detached, lies between the zygomatic arch above and the parotid duct below; this detached portion is named the *accessory part* of the gland.

The gland is enclosed within a capsule derived from the deep cervical fascia; the part covering the superficial surface of the gland is dense, closely adherent to the gland, and attached to the zygomatic arch; a portion of the fascia, attached to the styloid process and the angle of the mandible, is thickened to form the stylomandibular ligament, which intervenes between the parotid and submandibular glands.

The parotid gland may be described as roughly pyramidal in shape; it presents a small, superior surface, and superficial, anteromedial and postero-medial surfaces. The lower part of the gland tapers to a blunt extremity.

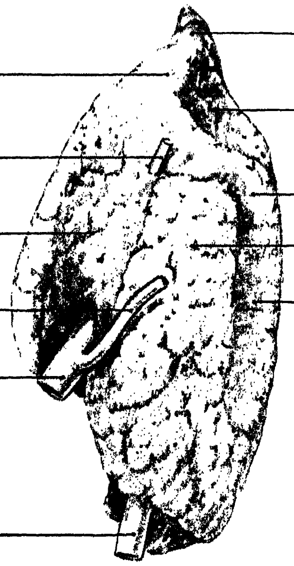
The *superior surface* is concave and is related to the external auditory meatus, and to the posterior surface of the mandibular joint; here the auriculotemporal nerve winds round the neck of the mandible, imbedded in the gland.

The *lower extremity* of the gland overlaps the posterior belly of the Digastric and the carotid triangle to a variable extent.

The *superficial surface* is covered with the skin, and the superficial fascia, which contains the facial branches of the great auricular nerve, some small lymph glands and the posterior border of the Platysma.

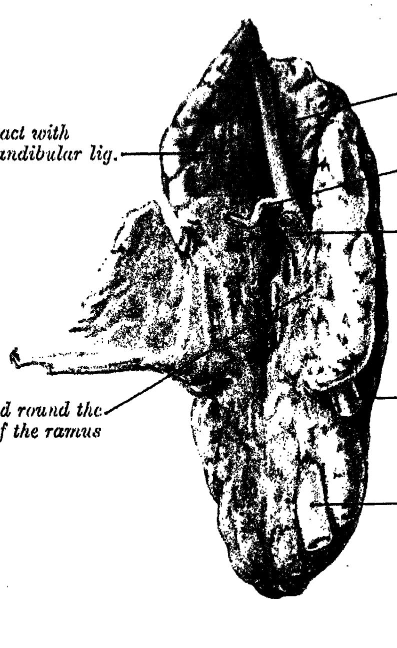
The *anteromedial surface* is grooved by the posterior border of the ramus of the mandible. It covers the postero-inferior part of the Masseter, the lateral

FIG. 1119.—The right parotid gland. Posteromedial aspect.



aspect of the mandibular joint and the adjoining part of the mandibular ramus, and passes forwards on the deep aspect of the ramus to reach the Medial

FIG. 1120.—The right parotid gland. Anteromedial aspect.



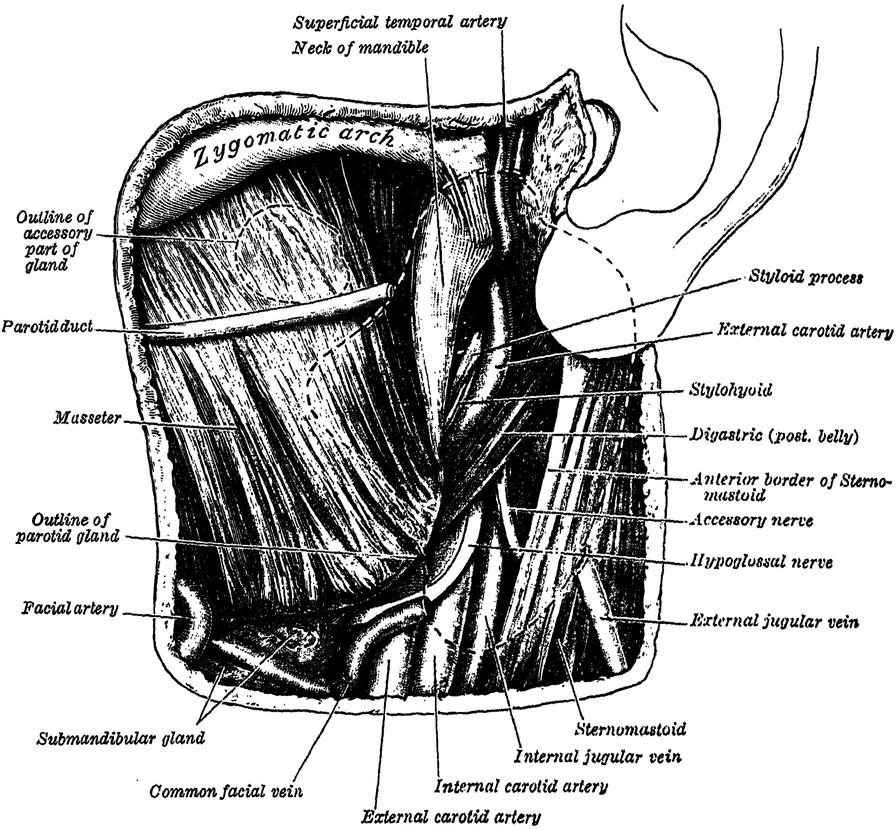
pterygoid muscle. The branches of the facial nerve emerge on the face from under cover of the anterior margin of this surface.

The *posteromedial surface* is moulded on the mastoid process and the Sterno-mastoid, and on the posterior belly of the Digastric, the styloid process and

the styloid group of muscles. The external carotid artery grooves this surface before it enters the substance of the gland. The internal carotid artery and internal jugular vein are separated from the gland by the styloid process and the styloid muscles (fig. 1121).

Structures within the gland.—The external carotid artery pierces the posteromedial surface of the parotid gland, and divides into its terminal branches within its substance. One of these branches—the (internal) maxillary artery—leaves the anteromedial surface of the gland, and runs forwards deep to the neck of the mandible, while the other—the superficial temporal artery—gives off its

Fig. 1121.—A drawing of a dissection to show the principal deep relations of the parotid gland.

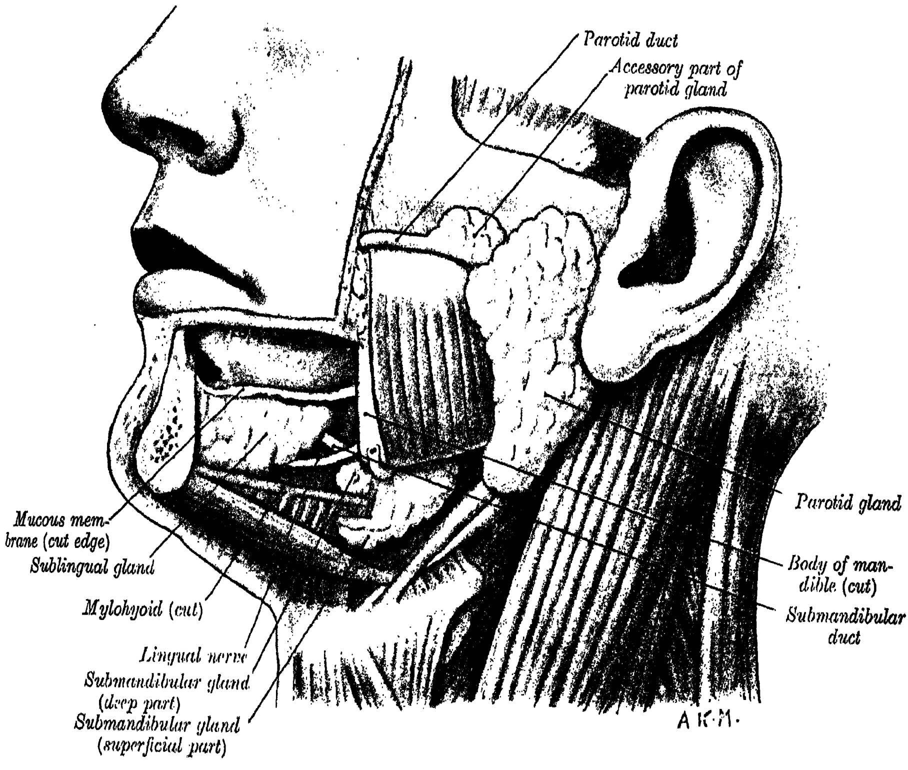


transverse facial branch, and then ascends to appear at the upper limit of the gland (fig. 1120). The posterior auricular artery may rise from the external carotid artery within the gland, and it then leaves the latter on its posteromedial surface. The posterior facial vein (p. 808), formed in the upper part of the gland by the union of the maxillary and superficial temporal veins, which enter the gland at the point of exit of the corresponding arteries, lies superficial to the intraglandular part of the external carotid artery. It passes downwards and divides into two branches which emerge one in front of and the other behind the inferior extremity of the gland. On a still more superficial plane the facial nerve traverses the gland. It enters the upper part of the posteromedial surface (fig. 1119), and passes forwards and downwards in two main divisions from which its terminal branches arise. These leave the anteromedial surface of the gland above, in front, and below, and pass to their destinations from under cover of its anterior margin.

The parotid duct (fig. 1122) is about 5 cm. long. It begins by numerous branches from the anterior part of the gland, crosses the Masseter, and at the anterior border of this muscle turns inwards nearly at a right angle, passes

through the corpus adiposum of the cheek and pierces the Buccinator; it then runs for a short distance obliquely forwards between the Buccinator and mucous membrane of the mouth, and opens upon a small papilla on the oral surface of the cheek opposite the second upper molar tooth. While crossing the Masseter it receives the duct of the accessory portion; in this position it lies between the upper and lower buccal branches of the facial nerve; the accessory part of the gland and the transverse facial artery are above it.

FIG. 1122.—A dissection showing the salivary glands of the left side.



Structure.—The wall of the parotid duct is of considerable thickness, and consists of a thick external fibrous coat which contains unstriped muscular fibres, and an internal mucous coat which is lined with short columnar epithelium. Its canal is about the size of a crow-quill, but at its orifice on the oral surface of the cheek its lumen is greatly reduced in size.

Vessels and Nerves.—The *arteries* supplying the parotid gland are derived from the external carotid artery, and from the branches given off by that vessel in or near the gland. The *veins* empty themselves into the external jugular vein, through some of its tributaries. The *lymph vessels* end in the superficial and deep cervical lymph glands, passing in their course through two or three lymph glands on the surface and in the substance of the parotid gland. The *nerves* are derived from the auriculotemporal nerve and from the plexus of the sympathetic on the external carotid artery. It is probable that the branch from the auriculotemporal nerve is the secretomotor nerve of the gland and that it is derived from the glossopharyngeal nerve through the otic ganglion; at all events, this has been proved experimentally to be the case in some of the lower animals.

The submandibular (submaxillary) gland (fig. 1122) is irregular in form and about the size of a walnut. It consists of a larger superficial part and a smaller deep part, which are continuous with each other around the posterior border of the Mylohyoid.

The *superficial part* of the submandibular gland is situated in the digastric triangle, reaching forwards to the anterior belly of the Digastric and backwards

to the stylomandibular ligament, which intervenes between the submandibular and parotid glands. Above, it extends under cover of the body of the mandible; below, it usually overlaps the intermediate tendon of the Digastric and the insertion of the Stylohyoid. It has three surfaces, an inferior, a lateral and a medial.

The *inferior surface* is covered with the skin, Platysma, and deep cervical fascia. It is crossed by the anterior facial vein, and by some filaments of the facial nerve; near the mandible the submandibular lymph glands are in contact with it.

The *lateral surface* is in relation with the submandibular fossa on the inner surface of the body of the mandible, and with the lower part of the medial surface of the Medial pterygoid muscle.

The *medial surface* is in relation with the Mylohyoid, Hyoglossus, Styloglossus, Stylohyoid, and posterior belly of the Digastric; between it and the Mylohyoid the mylohyoid nerve and vessels run forwards.

The facial (external maxillary) artery is imbedded in a groove in the posterior and superior part of the gland.

The *deep part* of the submandibular gland extends forwards as far as the posterior end of the sublingual gland, and lies in the intermuscular interval between the Mylohyoid below and laterally and the Hyoglossus and Styloglossus medially; above, it is related to the lingual nerve and submandibular (submaxillary) ganglion; below, to the hypoglossal nerve and its vena comitans.

The **submandibular duct** (submaxillary duct) is about 5 cm. long, and its wall is much thinner than that of the parotid duct. It begins by numerous branches in the superficial part of the gland, and runs with the deep part of the gland forwards between the Mylohyoid and the Hyoglossus; it then passes between the sublingual gland and the Genioglossus, and opens by a narrow orifice on the summit of the sublingual papilla (fig. 1141). On the Hyoglossus it lies between the lingual and hypoglossal nerves, but at the anterior border of the muscle it is crossed laterally by the lingual nerve; the terminal branches of the lingual nerve ascend on its medial side.

Vessels and Nerves.—The *arteries* supplying the submandibular gland are branches of the facial and lingual arteries. Its *veins* follow the course of the arteries. The *nerves* are derived from the submandibular ganglion, through which it receives filaments from the chorda tympani of the facial nerve, the lingual branch of the mandibular nerve and the sympathetic.

In the dog and cat the submandibular gland receives its nerve-supply through Langley's ganglion (p. 1272).

The **sublingual gland** (fig. 1122) is the smallest of the three salivary glands. It is situated beneath the mucous membrane of the floor of the mouth, at the side of the frenulum linguæ, in contact with the sublingual fossa on the inner surface of the mandible, close to the symphysis. It is narrow, flattened, shaped somewhat like an almond, and weighs between 3 and 4 gms. It is in relation, above, with the mucous membrane of the mouth, which it raises in the form of the sublingual fold; *below*, with the Mylohyoid; *in front*, with its fellow of the opposite side; *behind*, with the deep part of the submandibular gland; *laterally*, with the mandible above the anterior part of the mylohyoid line; and *medially*, with the Genioglossus, from which it is separated by the lingual nerve and the submandibular duct. Its excretory ducts are from eight to twenty in number. Of the *smaller sublingual ducts*, some join the submandibular duct: others open separately into the mouth, on the sublingual fold. One or more join to form the *principal sublingual duct*, which opens with or near to the submandibular duct.

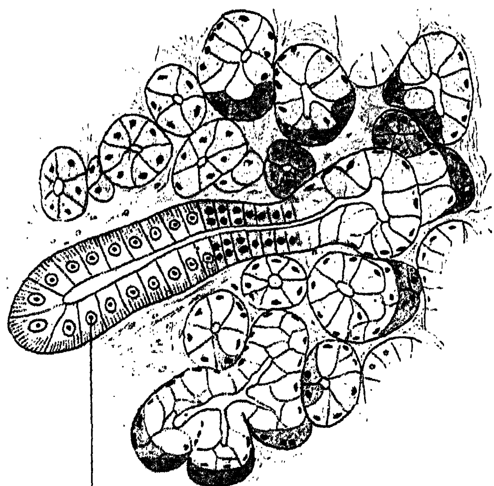
Vessels and Nerves.—The sublingual gland is supplied with blood by the sublingual and submental arteries. Its nerves are derived from the lingual and chorda tympani nerves, and from the sympathetic.

Structure of the salivary glands.—The salivary glands are compound racemose glands, consisting of numerous lobes, which are made up of lobules, connected together by dense areolar tissue, vessels and ducts. Each lobule consists of the ramification of a single duct, the branches ending in dilated ends or alveoli on which the capillaries are distributed. The

alveoli are enclosed by a basement-membrane, which is continuous with the membrana propria of the duct and consists of a network of branched and flattened nucleated cells.

The alveoli of the salivary glands are of two kinds, viz. serous and mucous, which differ in the nature of their secretion and in the appearance of their cells. (1) The mucous alveoli secrete a viscid fluid which contains mucin; (2) the serous secrete a thinner and more watery fluid. The sublingual gland consists of mucous, and the parotid gland of serous, alveoli. The submandibular gland contains both mucous and serous alveoli (fig. 1125).

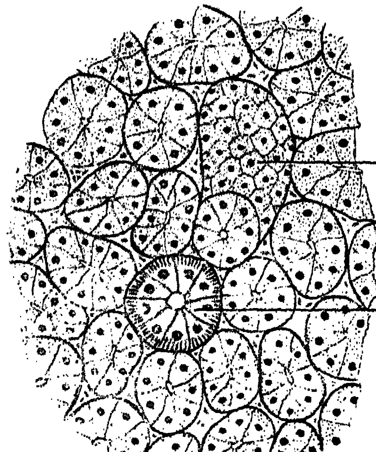
FIG. 1123.—A section through the submandibular gland of a kitten. Duct semi-diagrammatic. ×200.



The cells in the *mucous alveoli* are columnar in shape (fig. 1123), and in the fresh condition contain large granules of mucinogen. In hardened preparations a delicate protoplasmic network is seen, and the cells are clear and transparent. The nucleus is usually situated near the basement-membrane and is flattened.

In some alveoli peculiar crescentic bodies are seen between the cells and the basement-membrane. They are termed the *crescents of Giannuzzi*, or the *demilunes of Heidenhain* (fig. 1123), and are composed of polyhedral granular cells. Fine canaliculi pass between the mucus secreting cells to reach the demilunes and penetrate their cells.

FIG. 1124.—A section through the parotid gland of a cat. ×200.



In the resting condition of the gland the cells in the *serous alveoli* fill the cavity almost completely, so that the lumen is barely perceptible; they contain granules imbedded in a closely reticulated protoplasm (fig. 1124). The cells are more cubical than those of mucous alveoli; the nucleus of each is spherical and placed near the centre of the cell, and the granules are smaller.

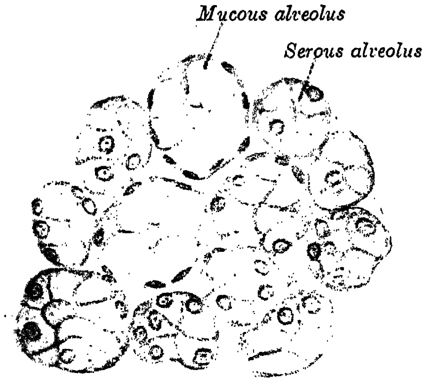
Both mucous and serous cells vary in appearance according to whether the gland is in a resting condition or has been recently active. In the former case the cells are large and contain many granules; in the latter case the cells are shrunken and contain few granules, chiefly collected at the inner ends of the cells. The granules are best seen in fresh preparations.

The ducts are lined at their origins by pavement epithelium, but as they enlarge, the

epithelial cells change to the columnar type, and the part of the cell next the basement-membrane is finely striated.

The lobules of the salivary glands are richly supplied with blood-vessels, which form a dense network in the inter-alveolar spaces. Fine plexuses of nerves are also found in the interlobular tissue. The nerve-fibrils pierce the basement-membrane of the alveoli, and end in branched varicose filaments between the secreting cells. In the hilum of the submandibular gland in some animals there is a collection of nerve-cells termed *Langley's ganglion.*

Fig. 1125.—A section through a human submandibular gland. Stained with hæmatoxylin and eosin. ×300.



Accessory glands.—Besides the salivary glands proper, numerous other glands are found in the mouth. Some of these occur in the tongue (p. 1289); others lie around and in the tonsil between its pits, and large numbers are present in the soft palate, the lips and cheeks. These glands are of the same structure as the larger salivary glands and are of the mucous or mixed type.

The Teeth [Dentes] (figs. 1127 to 1129)

Man is provided with two sets of teeth, which make their appearance at different periods of life. Those of the first set are temporary and appear during the first and second years; they are called the *deciduous* or *milk* teeth. Those of the second set begin to replace the deciduous set about the sixth year; they are all established by the twenty-fifth year, and, since they may continue until old age, are named the *permanent* teeth.

The *deciduous teeth* are twenty in number: four incisors, two canines, and four molars in each jaw.

The *permanent teeth* are thirty-two in number: four incisors, two canines, four premolars, and six molars in each jaw.

The dental formulæ may be represented as follows:

Deciduous Teeth.

	mol.	can.	in.	in.	can.	mol.	
Upper jaw . .	2	1	2	2	1	2	Total 20
Lower jaw . .	2	1	2	2	1	2	

Permanent Teeth.

	mol.	premol.	can.	in.	in.	can.	premol.	mol.	
Upper jaw .	3	2	1	2	2	1	2	3	Total 32
Lower jaw .	3	2	1	2	2	1	2	3	

General characteristics.—Each tooth consists of three portions: the *crown,* projecting beyond the gum; the *root,* imbedded in the alveolus; and the *neck,* the constricted portion between the crown and the root.

The roots of the teeth are firmly implanted in the alveoli of the maxillæ and mandible. Each alveolus is lined by periosteum (periodontal membrane), which invests the tooth as far as its neck and is continuous above with the fibrous tissue of the gums.

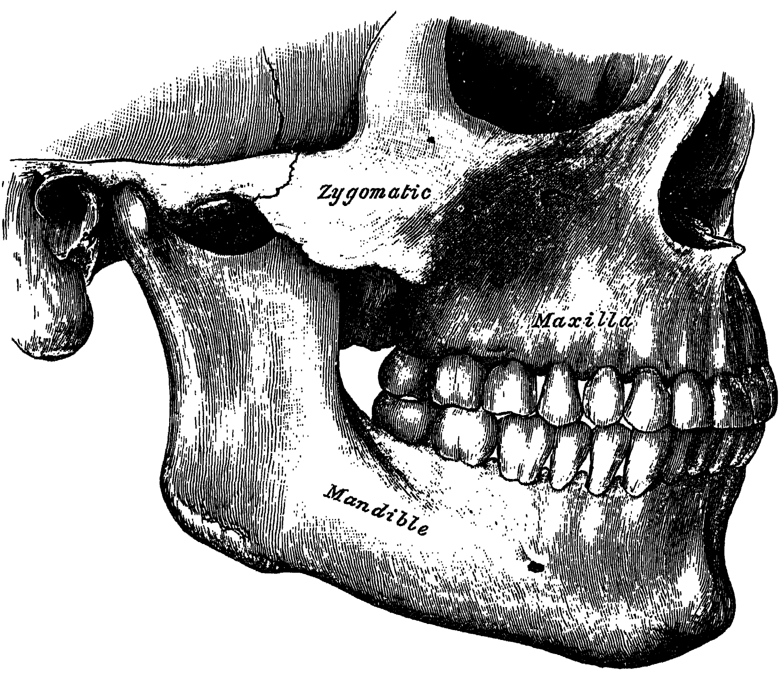
In consequence of the curve of the dental arch, terms such as anterior and posterior, if applied to the teeth, would be misleading and confusing. Special terms are therefore used to indicate the different surfaces of a tooth: the surface directed towards the lips or cheek is known as the *labial* or *buccal* surface; that directed towards the tongue is described as the *lingual* surface; those surfaces which touch neighbouring teeth are termed *contiguous surfaces.* In the case of the incisor and canine teeth the contiguous surfaces are medial and lateral; in the premolar and molar teeth they are anterior and posterior.

The superior dental arch is larger than the inferior, so that in the normal condition the teeth of the maxillæ slightly overlap those of the mandible both in front and at the sides. The upper central incisors are wider than the lower, and the corresponding teeth of the upper and lower sets are not opposed accurately to each other when the mouth is closed. Thus the upper canine tooth rests partly on the lower canine and partly on the first premolar, and the tubercles of the upper molar teeth lie behind the corresponding tubercles of the lower molar teeth. The dental arches, however, end at nearly the same points behind because the upper molars, especially the third, are smaller than the lower.

The Permanent Teeth (figs. 1126 to 1129)

The incisor teeth are so named because they present sharp cutting edges, adapted for biting the food. They are eight in number, and form the four front teeth in each dental arch.

Fig. 1126.—The teeth and jaws. Right lateral aspect.



The *crown* of each is directed vertically, and is chisel-shaped, being bevelled so as to present a sharp, horizontal, cutting edge. Before it is subjected to attrition, this edge presents three small prominent points separated by two notches. The crown is convex on its labial surface; concave on its lingual surface near the cutting edge, but becoming convex near the gum. In this situation in the teeth of the upper arch, it is frequently marked by a V-shaped eminence, known as the *cingulum*. The *neck* is constricted. The *root* is long, single, conical, transversely flattened, thicker in front than behind, and slightly grooved on each side.

The *upper incisors* are larger and stronger than the lower, and are directed obliquely downwards and forwards. They overlap the lower incisors and their free edges are consequently bevelled at the expense of their lingual surfaces. Their roots are conical and nearly cylindrical. The central upper incisors are larger than the lateral.

The *lower incisors* are smaller than the upper. They are placed vertically and are somewhat bevelled in front, where they have been worn down by contact with the overlapping edges of the upper teeth. Their roots are flattened

at the sides. The central lower incisors are slightly smaller than the lateral, and are the least of all the incisors.

The **canine teeth** are four in number, two in the upper, and two in the lower arch, one being placed lateral to each lateral incisor. They are larger and stronger than the incisors, and their long roots, which are relatively superficial, cause well-marked bony prominences.

The *crown* of each is large and conical, very convex on its labial surface, a little hollowed and uneven on its lingual surface, and tapering to a blunted point or cusp, which projects beyond the level of the other teeth. The *root* is single, but longer and thicker than that of the incisors ; it is conical in form, and marked by a slight groove on each side.

The *upper canine teeth* (popularly called *eye-teeth*) are larger and longer than the lower, and usually present a distinct cingulum.

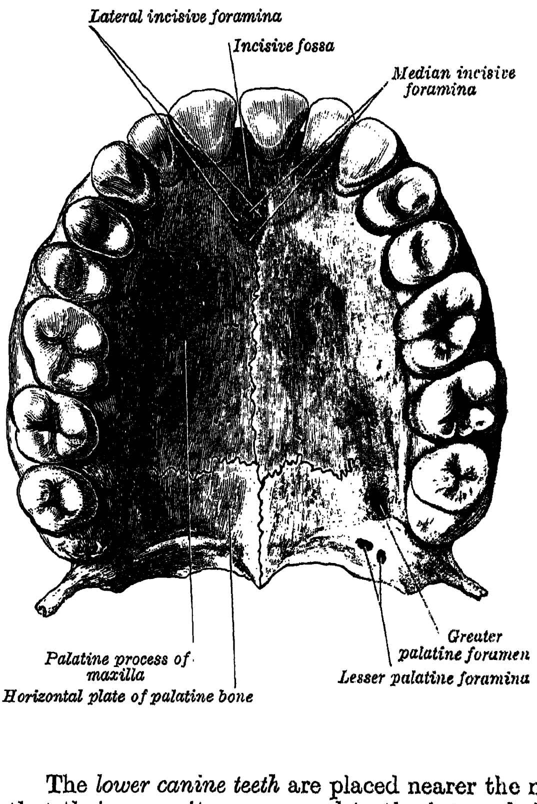


FIG. 1127.—The permanent teeth of the upper dental arch. Inferior aspect.

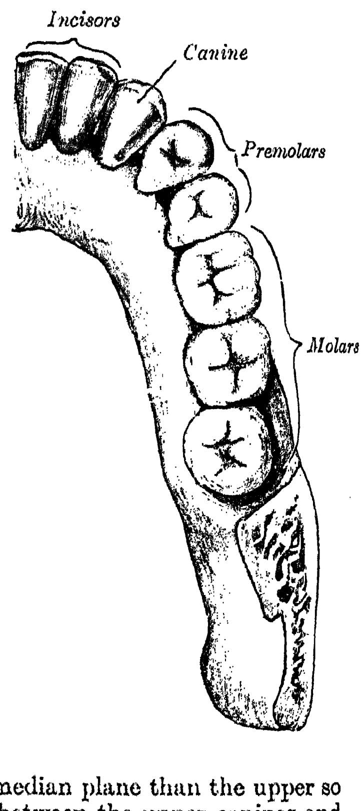


FIG. 1128.—The permanent teeth of the right half of the lower dental arch. Superior aspect.

The *lower canine teeth* are placed nearer the median plane than the upper so that their summits correspond to the intervals between the upper canines and lateral incisors. The roots of the lower canines are occasionally double.

The **premolar teeth** are eight in number, four in each arch. They are smaller and shorter than the canine teeth and are placed behind and lateral to them.

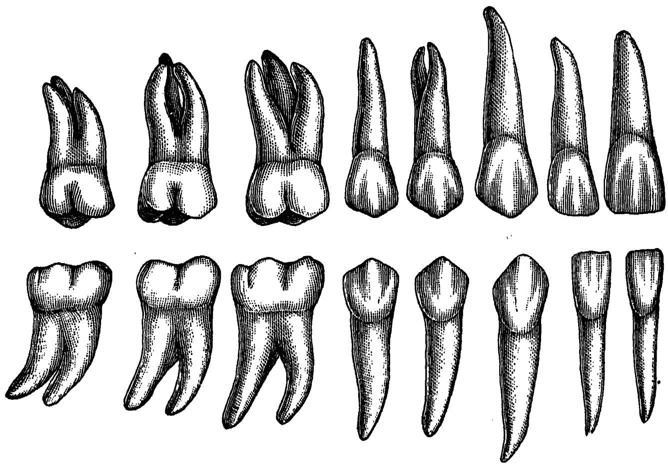
The *crown* of each is compressed from before backwards, and surmounted by two pyramidal tubercles separated by a groove. Of the two tubercles the labial is larger and more prominent than the lingual. The *neck* is oval. The *root* is generally single, but presents in front and behind a deep groove, which indicates a tendency in the root to become double.

The *upper premolars* are larger, and show a greater tendency to the division of their roots than the lower ; this is especially the case in the first upper premolar. The roots of the *lower premolars* are nearly cylindrical.

The **molar teeth** are the largest of the permanent set, and their broad crowns are adapted for grinding the food. They are twelve in number, six in each arch, three being placed behind each second premolar.

The *crown* of each is nearly cubical in form, convex on its buccal and lingual surfaces, and flattened on its surfaces of contact; it is surmounted by four or five tubercles, separated from each other by a cruciform depression. The *neck* is distinct, large and rounded.

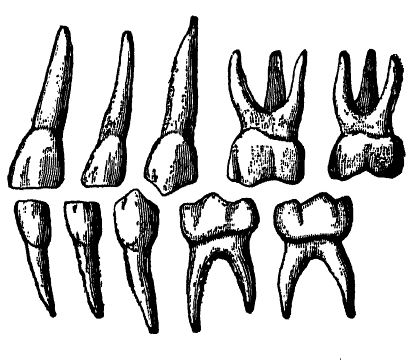
FIG. 1129.—The permanent teeth of the right side. (Burchard.)



The *upper molars*.—As a rule the first of the upper molars is the largest, and the third the smallest. The crown of the first has usually four tubercles, of which the posterior lingual tubercle is the smallest; that of the second, three or four; that of the third, three, the posterior lingual tubercle being absent. Each upper molar has three roots, two of which are buccal, and nearly parallel to each other; the third is lingual and diverges from the others as it ascends. The roots of the third molar (dens serotinus or wisdom-tooth) are more or less fused together.

The *lower molars*.—The lower molars are larger than the upper. On the crown of the first there are usually five tubercles, of which the posterior buccal tubercle is the smallest; on the crowns of the second and third, four or five, the posterior buccal tubercle being inconstant. Each lower molar has two roots, an anterior and a posterior, which are curved backwards; both roots are grooved longitudinally, indicating a tendency to division. The two roots of the third molar are more or less united.

FIG. 1130.—The deciduous teeth of the left side.



THE DECIDUOUS TEETH (fig. 1130)

The deciduous or milk-teeth resemble in form the teeth which bear the same names in the permanent set; they are, however, smaller and their necks are more constricted. The second molar is the largest of the deciduous teeth. The first upper molar has three tubercles, the second has four. The first lower molar has four tubercles; the second has five. The roots of the deciduous molars are smaller than those of the permanent molars; they are also more divergent, owing to the fact that the crowns of the permanent premolars are lodged between them. The deciduous molars are replaced by the permanent premolars.

THE STRUCTURE OF THE TEETH

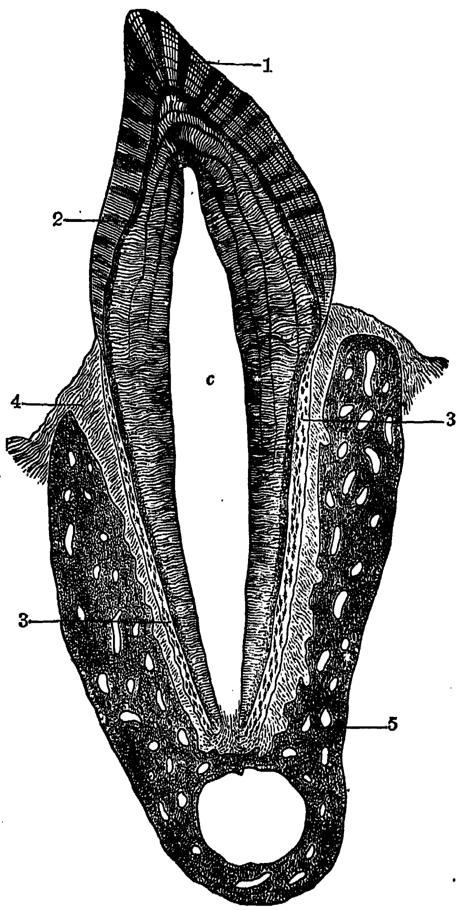
When a vertical section is made through a tooth (figs. 1131 to 1134), a cavity is seen in the crown and in the centre of each root; it opens by a minute orifice at the extremity of the latter. This is called the *pulp cavity*, and contains the *dental pulp*, a loose connective

tissue richly supplied with blood-vessels and nerves, which enter the cavity through the small foramen at the point of each root. Some of the cells of the pulp are arranged as a layer on the wall of the pulp cavity; they are named *odontoblasts*, and during the development of the tooth are columnar in shape, but after the dentine is fully formed they become flattened. Each sends a fine process into a canaliculus in the dentine.

The solid portion of the tooth consists of (1) the *dentine* or *ivory*, which forms the bulk of the tooth; (2) the *enamel*, which covers the exposed part of the crown; and (3) a thin layer of bone, termed the *cement*, which covers the root or roots.

The dentine (fig. 1131) is a modification of osseous tissue, from which, however, it differs in structure. On microscopic examination it is seen to consist of a number of minute wavy

Fig. 1131.—A vertical section through a tooth *in situ*. ×15.



c is placed in the pulp cavity, opposite the neck of the tooth; the part above it is the crown, that below is the root. 1. Enamel with radial and concentric markings. 2. Dentine with tubules and contour lines. 3. Cement with bone-cells. 4. Dental periosteum. 5. Mandible.

Fig. 1132.—A vertical section through a molar tooth.

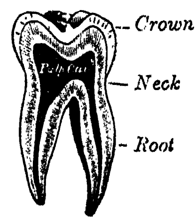
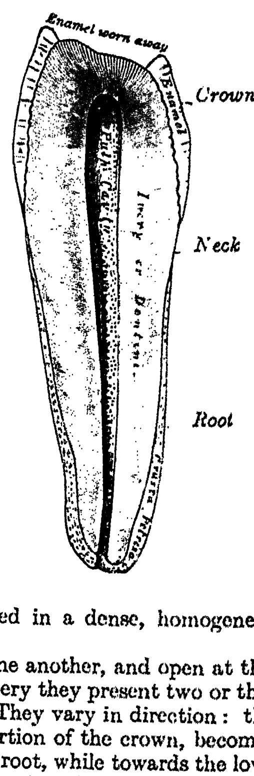


Fig. 1133.—A vertical section through a premolar tooth. (Magnified.)



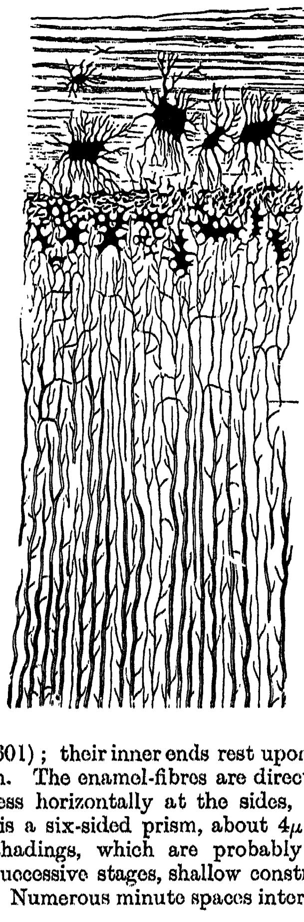
and branching tubes, termed the *dental canaliculi*, imbedded in a dense, homogeneous *matrix*.

The *dental canaliculi* (fig. 1134) are placed parallel with one another, and open at their inner ends into the pulp cavity. In their course to the periphery they present two or three curves, and are twisted on themselves in a spiral direction. They vary in direction: thus in a tooth of the mandible they are vertical in the upper portion of the crown, becoming oblique and then horizontal in the neck and upper part of the root, while towards the lower part of the root they are inclined downwards. In their course they divide and subdivide, and, especially in the root, give off minute branches, which join together in loops in the matrix, or end blindly. Near the periphery of the dentine, the finer ramifications of the canaliculi terminate imperceptibly by free ends. The dental canaliculi have definite walls consisting of an elastic homogeneous membrane, named the *dentinal sheath*, which resists

the action of acids; they contain slender cylindrical prolongations of the odontoblasts named *dentinal fibres*.

The *matrix* is translucent, and contains the chief part of the earthy matter of the dentine. It contains a number of fine fibrils, which are continuous with the fibrils of the dental pulp. After the earthy matter has been removed by the action of weak acid, the animal matter may be torn into laminæ which run parallel with the pulp cavity, and across the canaliculi. The planes separating these laminæ are indicated in a section of dry dentine by a series of somewhat parallel lines—the *contour lines of Owen*—composed of imperfectly calcified dentine. In consequence of the imperfection in the calcifying process, little irregular cavities are left, termed *interglobular spaces* (fig. 1134). A series of these spaces is found towards the outer surface of the dentine, where they form a layer which is sometimes known as the *granular layer of Tomes*. They have received their name from the fact that they are surrounded by minute nodules or globules of dentine. Other curved lines, named the *lines of Schreger*, may be seen parallel to the surface; they are due to the optical effect of simultaneous curvature of the dentinal fibres.

Fig. 1134.—A transverse section through a portion of the root of a canine tooth. ×300. (From Stricker's *Handbook of Histology*.)



Chemical composition.—According to Berzelius and von Bibra, dentine consists of 29 parts of animal, and 72 parts of earthy, matter. The animal matter is converted when boiled, into gelatin. The earthy matter consists of phosphate, carbonate, and a trace of fluoride of calcium, phosphate of magnesium and other salts; over 80 per cent. of the earthy matter consists of calcium phosphate.

The enamel is the hardest and most compact part of the tooth, and forms a thin crust over the exposed part of the crown, as far as the commencement of the root. It is thickest on the grinding surface of the crown, until worn away by attrition (fig. 1133), and becomes thinner towards the neck. The cement may overlap, or be overlapped by, the enamel, but they generally meet without overlapping. Sections usually show a series of brown lines which form acute angles with the contour of the underlying dentine. The enamel consists of minute parallel rods termed *enamel-prisms*, each of which is surrounded by a cuticle which can be deeply stained by Heidenhain's hæmatoxylin (H. C. Malleson, *British Dental Journal*, vol. xlv., p. 601); their inner ends rest upon the dentine, their outer form the free surface of the crown. The enamel-fibres are directed vertically on the summit of the crown, and more or less horizontally at the sides, but pursue a somewhat wavy course. Each enamel-fibre is a six-sided prism, about 4μ in diameter, and presents numerous, dark, transverse shadings, which are probably due to the manner in which the fibres are developed in successive stages, shallow constrictions being produced, as will be explained subsequently. Numerous minute spaces intervene between the enamel-fibres near their dentinal ends.

Chemical composition.—Enamel consists of from 98 to 99 per cent. of earthy matter, and from 1 to 2 per cent. of animal matter. The earthy matter consists of phosphate of lime, with traces of fluoride and carbonate of calcium, phosphate of magnesium and other salts. Tomes asserts that there is no animal matter in properly calcified enamel.

The cement (figs. 1131, 1134) is disposed as a thin layer on the roots of the teeth, from the enamel to the apex of each root. In structure and chemical composition it resembles bone. It contains a few lacunæ and canaliculi; the canaliculi of adjacent lacunæ intercommunicate as in ordinary bone; and those more deeply placed join with the adjacent dental canaliculi. Normal cement is non-vascular.

Arteries.—The upper molars and premolars receive their blood-supply from the posterior superior dental branch of the (internal) maxillary artery; the upper canine and incisors from the anterior superior dental branches of the infra-orbital artery. The lower teeth are supplied by the inferior dental branch of the maxillary artery.

Nerves.—The superior dental branches of the maxillary nerve supply the upper, and the inferior dental branch of the mandibular nerve (p. 1053) the lower, teeth. In the case

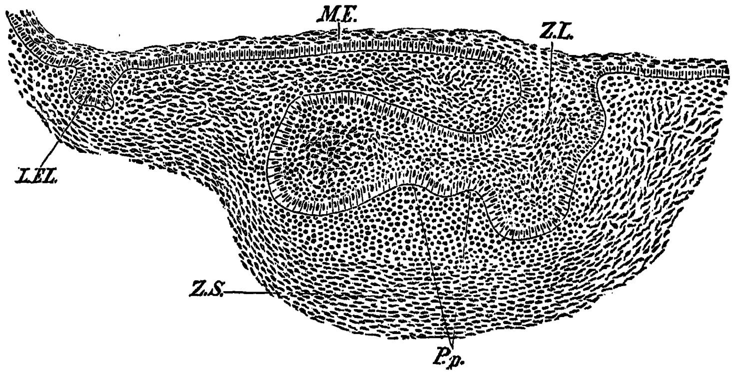
of the mandibular teeth, however, Stewart and Wilson * have shown that the lingual and buccal (buccinator) nerves may take part in the innervation of the pulp.

The *lymph vessels* are described on p. 855.

The Development of the Teeth (figs. 1135 to 1139)

In describing the development of the teeth, the mode of formation of the deciduous teeth must first be considered, and then that of the permanent teeth.

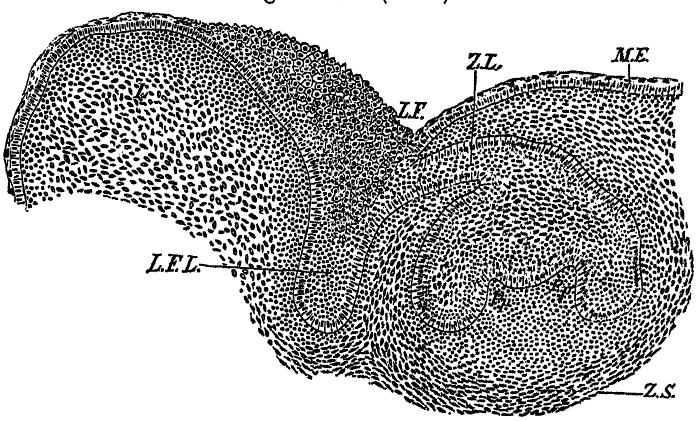
Fig. 1135.—A sagittal section through the first lower deciduous molar of a human embryo 30 mm. long. ×100. (Röse.)



L.E.L. Labiogingival lamina, here separated from the dental lamina. *M.E.* Mouth-epithelium. *P.p.* Bicuspidate papilla, capped by the enamel germ. *Z.L.*, placed over the shallow dental furrow, points to the dental lamina, which is spread out below to form the enamel germ of the future tooth. *Z.S.* Condensed tissue forming dental sac.

The development of the deciduous teeth begins about the sixth week of intrauterine life as a shallow *dental furrow* in the epithelium covering the surface of the mandibular arch (p. 97). Along the line of this furrow the epithelium grows into the subjacent mesoderm as a band of cells which splits into a medial (dentogingival) and a lateral (labiogingival) lamina (Bolk †). The cells of the labiogingival lamina ultimately break down and a groove is formed which

Fig. 1136.—A sagittal section through the canine tooth of an embryo 40 mm. long. ×100. (Röse.)



L.F. Alveololabial furrow. The other lettering as in fig. 1135.

separates the alveolar process from the lips and cheeks. In the dentogingival lamina the enamel-organs of the teeth are developed, and hence it is usually known as the *dental lamina* or *common dental germ*. Bolk has pointed out that the dental lamina also forms the epithelium of the gums, on the inner surface of the alveolar ridge. The common dental germ forms a flat band of cells, which grows into the substance of the embryonic jaw, at first horizontally, and then, as the teeth develop, vertically, i.e. upwards in the upper jaw, and downwards in

* *Proceedings of the Anatomical Society of Great Britain and Ireland*, June 1928.

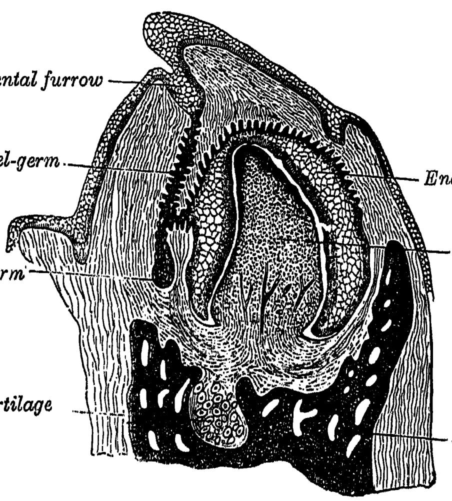
† L. Bolk, " Odontological Essays," *Journal of Anatomy*, vols. lv., lvi., lvii.

the lower jaw. While still maintaining a horizontal direction it has two edges—an *attached edge*, continuous with the epithelium lining the mouth, and a *free edge*, imbedded in the mesodermal tissue of the embryonic jaw.

About the ninth week the dental lamina begins to develop enlargements along its free edge. These are ten in number in each jaw, and each corresponds with a future deciduous tooth. They consist of masses of epithelial cells; and the cells of the deeper parts of each mass increase rapidly and spread in all directions. Each mass thus comes to assume the shape of a club, connected with the epithelial lining of the mouth by a narrow neck, embraced by mesoderm. These masses are now known as *special dental germs*. After a time the lower expanded portion of each mass inclines outwards, so as to form an angle with the superficial constricted portion, which is sometimes known as the *neck* of the special dental germ. About the tenth week the mesodermal tissue beneath the special dental germs becomes differentiated into papillæ; these come in contact with the special dental germs, which become folded over them like a hood or cap. There is, at this stage, a papilla (or papillæ) which has already begun to assume somewhat the shape of the crown of the future tooth, and from which the dentine and pulp of the tooth are developed, surmounted by a dome or cap of epithelial cells from which the enamel is derived.

While these changes are going on, the dental lamina extends backwards behind the special dental germ of the second deciduous molar tooth, and about the seventeenth week

Fig. 1137.—A vertical section through the mandible of an early human fœtus. ×25.



of intrauterine life, it presents an enlargement, the special dental germ for the first permanent molar, soon followed by the formation of a mesodermal papilla for the same tooth. About the fourth month after birth a further extension backwards of the dental lamina occurs, with the formation of another special dental germ and its corresponding papilla for the second molar. The process is repeated for the third molar, the papilla of which appears about the fifth year of life.

After the formation of the special dental germs, the dental lamina undergoes atrophic changes and becomes cribriform, except on the lingual aspect of each of the special germs of the temporary teeth, where it undergoes a local thickening to form the special dental germ of each of the successional permanent teeth—i.e. the ten anterior ones in each jaw. Here the same process goes on as has been described in connexion with those of the deciduous teeth: that is, they recede into the mesoderm, behind the germs of the deciduous teeth. As they recede they become club-shaped, form expansions at their distal ends, and finally meet papillæ which have been formed in the mesoderm. The apex of each papilla indents the dental germ, which forms a cap for it, and becomes converted into the enamel, while the papilla forms the dentine and pulp of the permanent tooth.

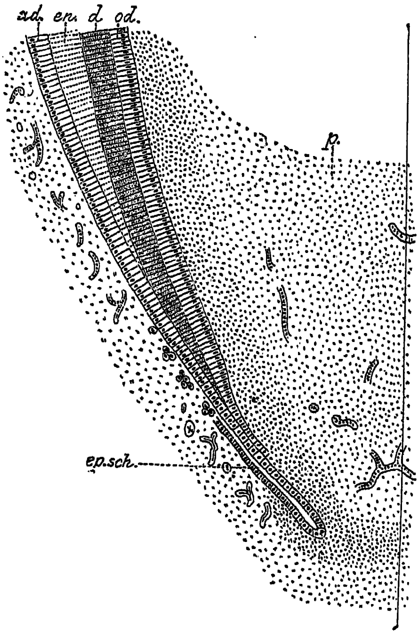
The special dental germs consist at first of round or polyhedral epithelial cells. After the formation of the papillæ, these cells undergo a differentiation into three layers. Those in contact with the papilla become elongated, and form a stratum of well-marked columnar epithelium. These cells form the enamel-fibres, and are therefore termed *enamel-cells* or *ameloblasts*. The cells of the outer layer of the special dental germ are cubical in form, and are named the *external enamel epithelium*. The intermediate cells become stellate in shape and form a network into which fluid is secreted; this has the appearance of a jelly, and to it the names of *stellate reticulum* or *enamel-pulp* are given. Between the stellate

reticulum and the layer of ameloblasts there is a *stratum intermedium* consisting of two or three layers of round or polygonal cells. The special dental germ, thus transformed, is now named the *enamel-organ* (fig. 1137).

Bolk (*loc. cit.*) has pointed out that in mammals, with one or two exceptions, the enamel-organ is, during a certain phase of development, connected with the common dental germ by a *medial* and a *lateral enamel band*, separated by what he names the *enamel-niche*. These two bands unite and convert the niche into a short tunnel which is filled with mesoderm, and is open posteriorly. The lateral enamel-band degenerates and is broken up into epithelial islets.

While these changes are going on, a sac is formed around each enamel-organ from the mesodermal tissue. This is known as the *dental sac*, and it is a vascular membrane of connective tissue. It encloses the whole tooth germ, and causes the neck of the enamel-organ to atrophy and disappear, so that the connexion between the enamel-organ and the superficial epithelium is severed.

Fig. 1138.—A longitudinal section through the lower part of a growing tooth, showing the extension of the layer of ameloblasts beyond the crown to mark off the limit of formation of the dentine of the root. (Röse.) (From Quain's *Elements of Anatomy.*)



ad. Ameloblasts, continuous below with *ep. sch.*, the epithelial sheath. *d.* Dentine. *en.* Enamel. *od.* Odontoblasts. *p.* Pulp.

The formation of the enamel.—The enamel is formed exclusively from the enamel-cells or ameloblasts of the special dental germ (fig. 1138), either by direct calcification of the columnar cells, which become elongated into the enamel-fibres, or, as is more generally believed, as a secretion from the ameloblasts, within which calcareous matter is subsequently deposited.

The process begins at the ends of the enamel-cells in contact with the dental papilla. Here a fine globular deposit takes place, being apparently shed from the ends of the ameloblasts. It is known by the name of the *enamel-droplet*, and resembles keratin in its resistance to the action of mineral acids. This droplet then becomes fibrous and calcifies, and forms the first layer of the enamel; a second droplet now appears and calcifies, and so on; successive droplets of keratin-like material are shed from the ameloblasts and form layers of enamel, the ameloblasts gradually receding as each layer is produced, until at the termination of the process they have almost disappeared. The enamel-pulp or stellate reticulum and the stratum intermedium atrophy and disappear, so that the newly formed calcified material and the external enamel-epithelium come into apposition. The crown of the tooth is covered for a time by a distinct membrane, known as the *cuticula dentis* (*Nasmyth's membrane*), and believed to be developed from the enamel-epithelium. It forms a horny layer, which may be separated from the subjacent calcified mass by the action of strong acids. It is marked by the hexagonal impressions of the enamel-fibres, and when stained by nitrate of silver, shows the characteristic lines of interepithelial cement.

The formation of the dentine.—As before stated, the first germs of the dentine are the papillæ, which grow upwards into the enamel-germs and become covered by them, both being enclosed in the dental sacs, in the manner above described. Each papilla then consists of round cells, and is very vascular, and soon begins to assume the shape of the future tooth. The next step is the appearance of the *odontoblasts*, which have a relation to the development of the teeth somewhat similar to that of the osteoblasts to the formation of bone; they are formed from the superficial cells of the papilla; these cells become elongated, one end of the elongated cells resting against the epithelium of the special dental germs, the other being tapered and often branched. By the direct transformation of the peripheral ends of these cells, or by a secretion from them, a layer of uncalcified matrix (*prodentine*) is formed, which caps the cusp, or cusps if there be more than one, of the papilla. This matrix becomes fibrillated, and in it islets of calcification make their appearance, and, coalescing, give rise to a continuous layer of calcified material, which covers each cusp and constitutes the first layer of dentine. The odontoblasts retire towards the centre of the papilla, and, as they do so, produce successive layers of dentine—that is to say, they form the dentinal matrix in which calcification subsequently takes place. As they recede from

the periphery of the papilla, they leave behind them filamentous processes of cell-protoplasm; these are surrounded by the calcified material, and thus the dental canaliculi are formed; the processes of protoplasm contained within these constitute the dentinal fibres. The central part of the papilla does not undergo calcification, but persists as the pulp of the tooth. In certain places uncalcified portions of the matrix remain between the successive layers of dentine, and give rise to the interglobular spaces alluded to above.

The formation of the cement.—The root of the tooth begins to be formed shortly before the crown emerges through the gum, but is not completed until some time afterwards. Its form is determined by a downgrowth of the epithelium of the dental germ which extends below the region where the enamel is to be formed, almost as far as the situation of the apex of the future root; this fold of epithelium is known as the *epithelial sheath* (fig. 1138). The vascular tissues of the dental sac then break through the epithelial sheath, and spread over the surface of the root as a layer of bone-forming material. In this layer osteoblasts make their appearance, and the process of ossification goes on as in the intramembranous ossification of bone. The remains of the epithelial sheath may sometimes be seen in the adult as isolated groups of cells in the alveolar periosteum (periodontal membrane).

The formation of the alveoli.—About the fourteenth week of embryonic life the dental lamina is enclosed in a trough or groove of mesodermal tissue, which at first is common to all the dental germs, but subsequently is divided by septa into loculi, each loculus containing the special dental germ of a deciduous tooth and its corresponding permanent tooth. After birth each cavity becomes subdivided, so as to form separate loculi for each deciduous tooth and its corresponding permanent tooth. Although at one time the whole of the growing tooth is contained in the cavity of the alveolus, the latter never completely encloses it, since there is always an aperture over the top of the crown filled by soft tissue, by which the dental sac is connected with the surface of the gum, and which in the permanent teeth is called the *gubernaculum dentis.*

The development of the permanent teeth—Developmentally considered the permanent teeth may be divided into two sets: (1) the *successional permanent teeth* which replace the deciduous teeth, and, like them, are ten in number in each jaw; and (2) the *superadded permanent teeth* which have no deciduous predecessors, but are developed behind the temporary molars. The superadded permanent teeth are the three permanent molars, the molars of the deciduous set being replaced by the permanent premolars. During their development the successional permanent teeth, enclosed in their sacs, are placed on the lingual side of the deciduous teeth, but are separated from them by bony partitions. As the crown of the permanent tooth grows, absorption of the bony partition and of the root of the deciduous tooth takes place, through the agency of *osteoclasts*, which appear at this time, and finally nothing but the crown of the deciduous tooth remains. This is shed or removed, and the permanent tooth takes its place.

The superadded permanent teeth are developed in the manner already described, by extensions backward of the posterior part of the dental lamina in each jaw (p. 1278).

The *eruption of the teeth.*—When the calcification of the different tissues of the tooth is sufficiently advanced to enable it to bear the pressure to which it will be subjected, eruption takes place, the tooth making its way through the gum. The eruption of the deciduous teeth commences about the seventh month after birth, and is completed about the end of the second year, the teeth of the lower jaw preceding those of the upper.

C. S. Tomes gives the following as the most usual times of eruption of the deciduous teeth:

Lower central incisors	6 to 9 months
Upper incisors	8 to 10 months
Lower lateral incisors and first molars . .	15 to 21 months
Canines	16 to 20 months
Second molars	20 to 24 months

There are, however, considerable variations in these times. According to Holt: a child at the age of one year should have six teeth; at the age of a year and half, twelve; at the age of two years, sixteen; and at the age of two and a half years, twenty.

Calcification of the permanent teeth proceeds in the following order in the lower jaw (in the upper jaw it takes place a little later): the first molars, at birth; the incisors, and canines, about six months after birth; the premolars, at the third year, or a little later; the second molars, about the end of the fourth year; the third molars, about the tenth year.

The eruption of the permanent teeth takes place at the following

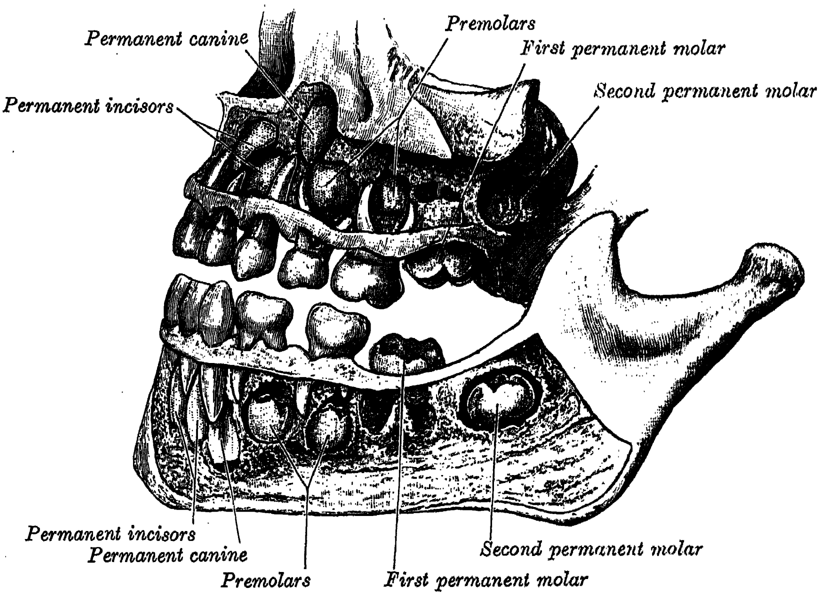
periods, the teeth of the lower jaw preceding those of the upper by short intervals:

First molars	6th year
Two central incisors	7th year
Two lateral incisors	8th year
First premolars	9th year
Second premolars	10th year
Canines	11th to 12th year
Second molars	12th to 13th year
Third molar	17th to 25th year

Towards the sixth year, before any of the deciduous teeth are shed, there are twenty-four teeth in each jaw, viz. the ten deciduous teeth and the crowns of all the permanent teeth except the third molars (fig. 1139).

It should be noted that the first molars are the earliest of the permanent teeth to erupt. This arrangement provides for the satisfactory mastication of food during the period when the premolars are erupting and the milk molars,

Fig. 1139.—The teeth of a child about six years. The permanent teeth are coloured *blue*.



which are in process of being shed, are of little value for this purpose. It is of interest to observe that in the eruption of both the deciduous and the permanent teeth, the canine appears in the interval between two teeth which have already erupted.

Development of the gums.—West,* who has investigated the development of the gums in human embryos and fœtuses from the seventh to the fortieth week, points out that the gum is developed in two parts, a labiobuccal and a lingual. The *labiobuccal part* lies between the lip-groove and the dental-groove. It appears before the lingual part, grows more rapidly, and is the more prominent; it takes the chief share in the formation of the adult gum, and becomes divided into segments which correspond in size and number with the tooth-sacs. The *lingual part* is not segmented, and its surface remains almost entirely smooth. The tissue of the gum in advance of the tooth is highly vascular, and furnishes a source of nutrition for the developing tooth.

Applied Anatomy.—As a consequence of diseases such as the acute infective fevers, which cause a temporary diminution in the calcium content of the blood, both the deciduous and the permanent teeth may show defective development or irregular transverse furrows

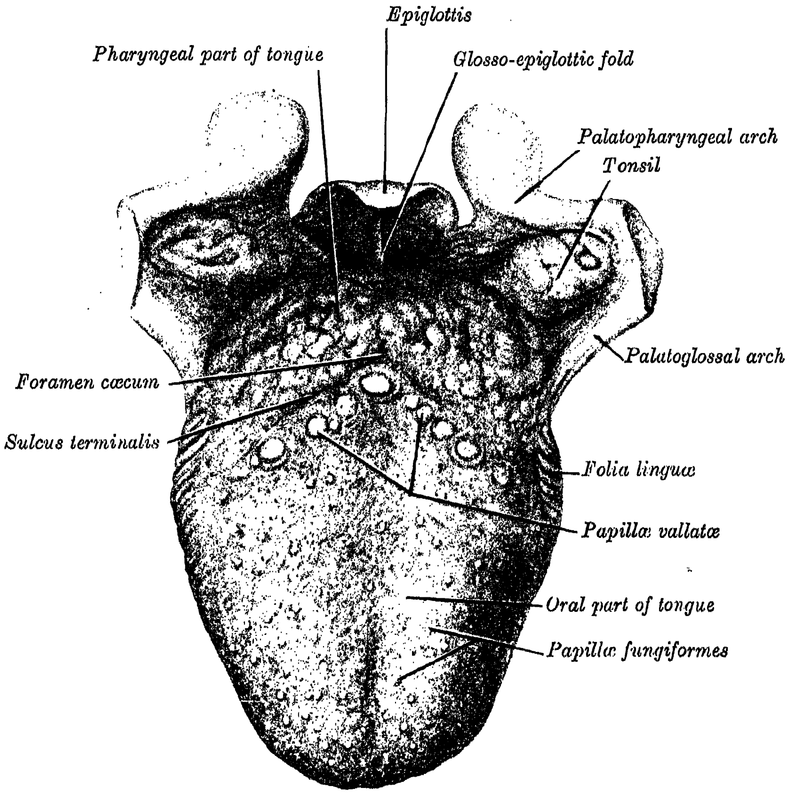
* Cecil M. West (Contributions to Embryology, No. 79. Publication 361 of the Carnegie Institution of Washington, 1925.)

and erosions ; this is particularly the case with the incisors. A characteristic malformation of the two upper central permanent incisors is seen in patients with inherited syphilis, and was first described by Hutchinson. Here there is a crescentic notch in the anterior surface and at the cutting edge of the tooth, which is peg-shaped, stunted, and set obliquely in the gum, pointing either medially or laterally.

The Tongue [Lingua] (figs. 1140 to 1142)

The **tongue** is a muscular organ intimately associated with the functions of taste, speech and deglutition ; it is situated partly in the mouth, and partly in the pharynx. Through the medium of its constituent muscles it is attached to the hyoid bone, the mandible, the styloid processes, the soft palate and the wall of the pharynx. It possesses a root, a tip, a curved dorsum and an inferior surface.

Fig. 1140.—The dorsum of the tongue.

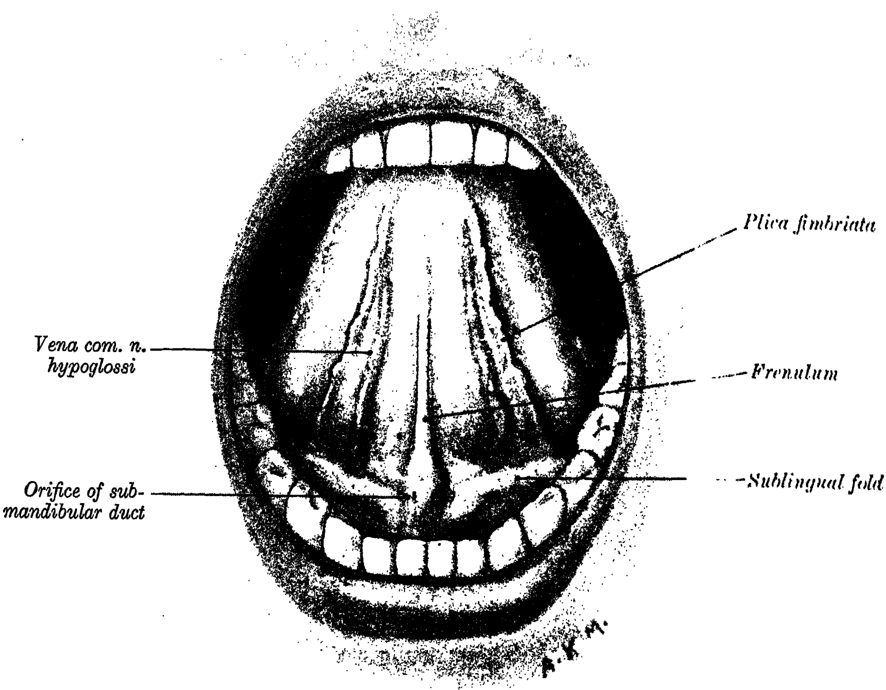


The *root* of the tongue (fig. 1117) is attached to the hyoid bone and the mandible, and between these bones is in contact with the Geniohyoid and the Mylohyoid muscles. The *dorsum* is convex from before backwards, and from side to side, and is divided into an anterior part which faces upwards, and a posterior part which faces backwards. These two parts are separated by a V-shaped furrow, termed the *sulcus terminalis*, the limbs of which run laterally and forwards from a median pit, named the *foramen cæcum*, to the palatoglossal arches (fig. 1140). The foramen cæcum marks the site of the upper end of the thyroid diverticulum (p. 165), and the sulcus terminalis serves as the boundary between the oral part or anterior two-thirds, and the pharyngeal part or posterior one-third, of the tongue. These two parts differ in the structure of their covering mucous membrane, in their nerve supply and in their development.

The *oral part* of the tongue (figs. 1140, 1142) is placed in the cavity and floor of the mouth ; its *apex* rests against the incisor teeth ; its *margin* is free and in contact with the gums and teeth ; its *superior surface* is in relation with the hard and soft palates. On each border, just in front of the palatoglossal

arch, there are four or five vertical folds, named the *folia linguæ* (fig. 1140), which correspond to the papillæ foliatæ of the rabbit's tongue. The mucous membrane of the superior surface of the oral part is marked by a median furrow (figs. 1140, 1142), is intimately adherent to the subjacent muscle, and is covered with papillæ. The mucous membrane on the inferior surface is smooth, and of a purplish colour ; it is reflected from the tongue to the floor of the mouth and the gums. In the median plane it is connected to the floor of the mouth by the frenulum linguæ (fig. 1141). Lateral to the frenulum, the lingual vein is seen shining through the mucous membrane, and at the lateral side of the vein there is a fringed fold of mucous membrane, named the *plica fimbriata*, which is directed forwards and medially towards the apex. The oral part of

FIG. 1141.—The cavity of the mouth. The tip of the tongue is turned upwards.



Note.—In the model from whom the drawing was made the two sublingual papillæ formed a single median elevation.

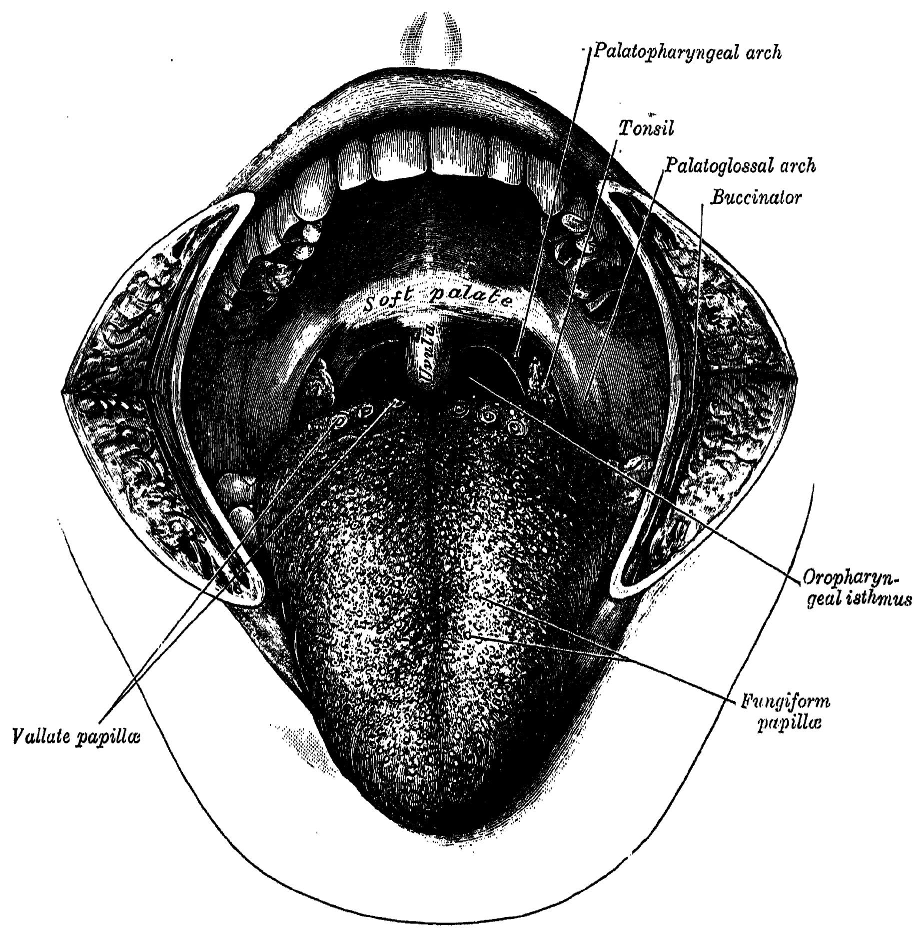
the tongue is developed from the lingual swellings of the mandibular arch, and to a small extent from the tuberculum impar (p. 163). Its nerve of ordinary sensation is the lingual ; its nerve of taste, the chorda tympani.

The *pharyngeal part* of the tongue (fig. 1140) lies behind the palatoglossal arches and the oropharyngeal isthmus ; its posterior surface (sometimes named the *base* of the tongue) forms the anterior wall of the oral part of the pharynx. The mucous membrane covering it is reflected laterally on to the tonsils and the pharyngeal wall, and posteriorly on to the epiglottis, where it forms a median [glosso-epiglottic] fold, and two lateral [pharyngo-epiglottic] folds. It is devoid of papillæ, but exhibits a number of low elevations, due to the presence of underlying nodules of lymphoid tissue, which are imbedded in the submucous tissue and collectively constitute the *lingual tonsil*. The pharyngeal part of the tongue is developed from the hypobranchial eminence, which is described on p. 164. Its nerves of ordinary sensation and of taste are derived from the glossopharyngeal.

The *papillæ of the tongue* (figs. 1140, 1142) are projections of the corium. They are thickly distributed over the anterior two-thirds of the dorsum, giving to this part its characteristic roughness. They are grouped under the terms papillæ vallatæ, papillæ fungiformes, papillæ filiformes and papillæ simplices.

The *vallate papillæ* (figs. 1140, 1142) are of large size, and vary from eight to twelve in number. They are situated on the dorsum of the tongue, and form a V-shaped row immediately in front of and parallel with the sulcus terminalis. Each papilla is from 1 mm. to 2 mm. in diamater, and is attached within a

FIG. 1142.—The cavity of the mouth. The cheeks have been slit transversely and the tongue pulled forwards.

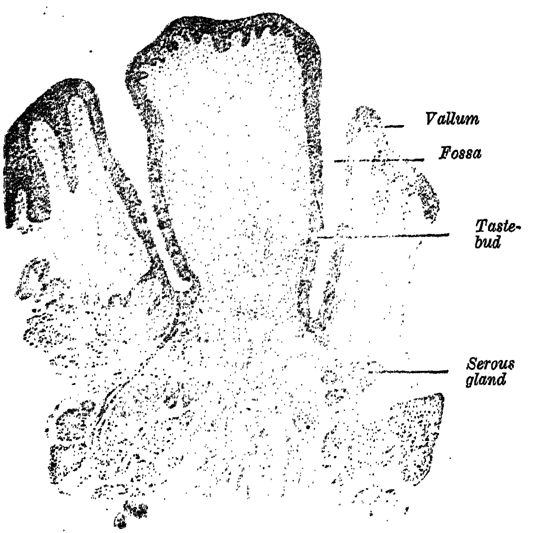


circular depression of the mucous membrane; each depression is surrounded by a wall (vallum) separated from the papilla by a circular sulcus. The papilla is shaped like a truncated cone, the smaller end being attached to the tongue; the broader end projects a little above the surface of the tongue, and is studded with numerous small secondary papillæ subjacent to the epithelial layer. The entire papilla and the surrounding sulcus are covered with stratified squamous epithelium.

The *fungiform papillæ* (figs. 1140, 1142, 1144), more numerous than the preceding, are found chiefly at the sides and apex of the tongue, but are scattered irregularly and sparingly over the dorsum. They are easily distinguished from the filiform papillæ by their large size, round shape, and deep red colour; each exhibits secondary papillæ beneath the epithelium. On the sides of the tongue they are somewhat flattened.

The *filiform papillæ* (fig. 1145) cover the anterior two-thirds of the dorsum of the tongue. They are very minute, conical or cylindrical in shape, and arranged in rows which run parallel with those of the papillæ vallatæ, excepting at the apex of the tongue, where their direction is transverse. The filiform papillæ present numerous, secondary, connective tissue papillæ, but these are more pointed and contain a larger proportion of elastic fibres than the secondary papillæ vallatæ and papillæ fungiformes. The epithelium covering the filiform papillæ may be split up into filamentous processes, each of which forms the apex of one of the secondary papillæ; these processes are of a whitish tint, owing to the thickness and density of the epithelium, the cells of which are elongated and cornified.

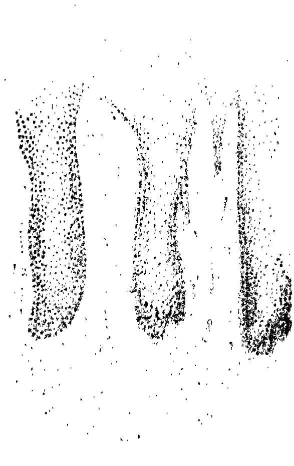
Fig. 1143.—A vertical section through a human vallate papilla. Stained with hæmatoxylin and eosin. ×15.



The *papillæ simplices* are similar to those of the skin, and cover the whole of the mucous membrane of the tongue, as well as the larger papillæ. They consist of closely set microscopic elevations of the corium; each contains a capillary loop, and is covered with epithelium.

Fig. 1144.—A section through a fungiform papilla from the human tongue, Stained with hæmatoxylin and eosin. ×15.

Fig. 1145.—A section through two filiform papillæ from the human tongue. Stained with hæmatoxylin and eosin. ×15.



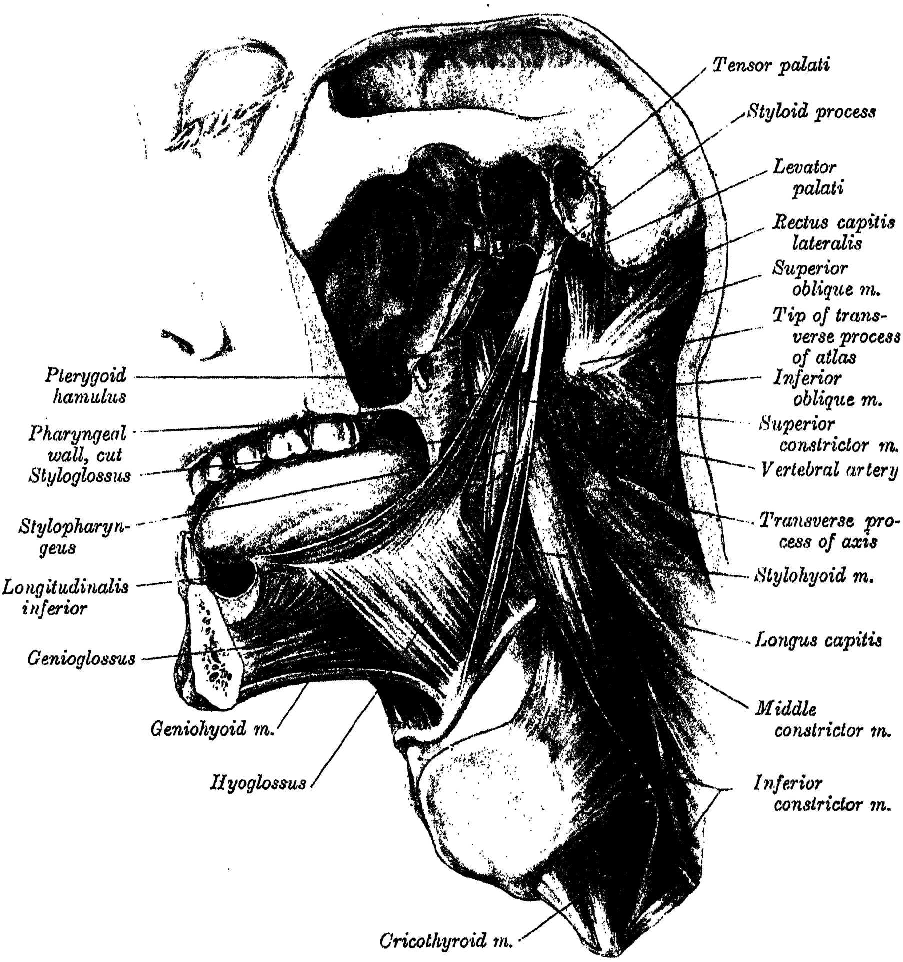
The muscles of the tongue.—The tongue is divided into right and left halves by a median fibrous septum, which is fixed below to the hyoid bone. In each half there are two sets of muscles, extrinsic and intrinsic; the former have their origins outside the tongue, the latter are contained within it.

The *extrinsic muscles* (fig. 1146) are :

Genioglossus. Chondroglossus.
Hyoglossus. Styloglossus.
Palatoglossus *

The **Genioglossus** is a triangular muscle placed close to and parallel with the median plane. It arises by a short tendon from the upper genial tubercle on the inner surface of the symphysis of the mandible, just above the origin of the Geniohyoid muscle, and spreads out in a fan-like form. The inferior

FIG. 1146.—A dissection of the left side of the head and neck, showing the muscles of the tongue and pharynx.



fibres are attached by a thin aponeurosis to the upper part of the body of the hyoid bone, a few passing between the Hyoglossus and Chondroglossus to blend with the Constrictors of the pharynx ; the middle fibres pass backwards, and the superior ones upwards and forwards, to enter the whole length of the under surface of the tongue, from the root to the apex. The muscles of opposite sides are separated posteriorly by the septum of the tongue (p. 1289) ; in front, they are more or less blended owing to the decussation of fasciculi in the median plane.

Actions.—The Genioglossus draws the tongue forwards and protrudes the

* The Palatoglossus, although one of the muscles of the tongue, is more closely associated with the soft palate both in situation and function ; it is consequently described with the muscles of that structure (p. 1265).

tip from the mouth. The two muscles acting in their entirety draw the median part of the tongue downwards so as to make the superior surface concave from side to side.

The **Hyoglossus**, thin and quadrilateral, arises from the whole length of the greater horn, and from the front of the lateral part of the body, of the hyoid bone; it passes almost vertically upwards and enters the side of the tongue, between the Styloglossus and Longitudinalis linguæ inferior. The fibres arising from the body of the hyoid bone overlap those from the greater horn.

Relations.—The Hyoglossus is in relation by its *superficial surface* with the tendon of the Digastric, the Stylohyoid, Styloglossus and Mylohyoid muscles, the lingual nerve and the submandibular ganglion, the sublingual gland, the deep portion of the submandibular gland and the submandibular duct, the hypoglossal nerve and its vena comitans. By its *deep surface* it is in relation with the stylohyoid ligament, the Genioglossus, the Longitudinalis linguæ inferior, and the glossopharyngeal nerve. In its lower and posterior part, it is separated from the Middle constrictor of the pharynx by the lingual vessels. This portion of the muscle lies in the lateral wall of the pharynx, a little below the tonsil.

Action.—The Hyoglossus depresses the tongue.

The **Chondroglossus** is sometimes described as a part of the Hyoglossus, but it is separated from that muscle by fibres of the Genioglossus which pass to the side of the pharynx. It is about 2 cm. long, and arises from the medial side and base of the lesser horn and contiguous portion of the body of the hyoid bone; it ascends and blends with the intrinsic muscular fibres of the tongue, between the Hyoglossus and Genioglossus.

A small slip arises occasionally from the cartilago triticea in the lateral thyrohyoid ligament and enters the tongue with the most posterior fibres of the Hyoglossus.

Action.—The Chondroglossus assists the Hyoglossus in depressing the tongue.

The **Styloglossus**, the shortest and smallest of the three styloid muscles, arises from the anterior and lateral surfaces of the styloid process, near its apex, and from the stylomandibular ligament. Passing downwards and forwards, it divides upon the side of the tongue into two portions; one, longitudinal, enters the side of the tongue near its dorsal surface, blending with the fibres of the Longitudinalis linguæ inferior in front of the Hyoglossus; the other, oblique, overlaps the Hyoglossus and decussates with its fibres (fig. 1146).

Action.—The Styloglossus draws the tongue upwards and backwards.

Nerve-supply.—With the exception of the Palatoglossus (p. 1265) all the extrinsic muscles of the tongue are supplied by the hypoglossal nerve.

The *intrinsic muscles* are:

Longitudinalis linguæ superior.	Transversus linguæ.
Longitudinalis linguæ inferior.	Verticalis linguæ.

The **Longitudinalis linguæ superior** is a thin stratum of oblique and longitudinal fibres immediately underlying the mucous membrane on the dorsum of the tongue. It arises from the submucous fibrous layer close to the epiglottis, and from the median fibrous septum, and runs forward to the edges of the tongue, some of its fibres being inserted into the mucous membrane.

The **Longitudinalis linguæ inferior** is a narrow band situated on the under surface of the tongue between the Genioglossus and Hyoglossus. It extends from the root to the apex of the tongue, some of its posterior fibres being connected with the body of the hyoid bone; in front it blends with the fibres of the Styloglossus.

The **Transversus linguæ** consists of fibres which arise from the median fibrous septum and pass laterally to be inserted into the submucous fibrous tissue at the sides of the tongue.

The **Verticalis linguæ** is found at the borders of the fore part of the tongue. Its fibres extend from the upper to the under surface of the organ.

Applied Anatomy.—Owing to the presence of the median fibrous septum of the tongue, the anastomosis between the two lingual arteries is not very free. This is a point of considerable importance in connexion with removal of one-half of the tongue, an operation not infrequently resorted to for malignant disease. If the mucous membrane be divided exactly in the median plane, the tongue can be split into halves, without any appreciable hæmorrhage, and the diseased half can then be removed.

Nerve-supply.—The intrinsic muscles of the tongue are supplied by the hypoglossal nerve.

Actions.—The intrinsic muscles are mainly concerned in altering the shape of the tongue; thus, the Longitudinales linguæ, superior et inferior, tend to shorten it, but the former, in addition, turns the tip and sides upwards so as to render the dorsum concave, while the latter pulls the tip downwards and renders the dorsum convex. The Transversus linguæ narrows and elongates the tongue, and the Verticalis linguæ flattens and broadens it.

Structure of the tongue.—The tongue consists chiefly of muscular tissue, but is partly invested by mucous membrane and a submucous fibrous layer.

The mucous membrane covering the under surface of the tongue is thin, smooth, and identical in structure with that lining the rest of the oral cavity. The mucous membrane of the pharyngeal part of the dorsum of the tongue is thick and freely movable over the subjacent parts. It contains a large number of follicles of lymphoid tissue; each follicle forms a rounded eminence, in the centre of which there is a minute orifice leading into a funnel-shaped cavity or recess; numerous round or oval nodules of lymphoid tissue, each enveloped by a capsule derived from the submucous fibrous layer, are grouped around this recess, which receives the openings of the ducts of some mucous glands in its floor. The mucous membrane on the oral part of the dorsum of the tongue is thin, intimately adherent to the muscular tissue, and covered with numerous *papillæ* (p. 1285). It consists of a layer of connective tissue (the *corium*) covered with epithelium.

The epithelium is of the stratified squamous variety, similar to, but much thinner and less complex than that of the skin; it invests each papilla from root to summit.

The *corium* consists of a dense felt-work of fibrous connective tissue, with numerous elastic fibres, firmly united with the fibrous tissue between the muscular bundles of the tongue. It contains the ramifications of the numerous vessels and nerves from which the papillæ are supplied, large plexuses of lymph vessels and the glands of the tongue.

Glands of the tongue.—The tongue is provided with mucous and serous glands.

The *mucous glands* are similar in structure to the labial and buccal glands. They are numerous in the posterior one-third of the tongue, i.e. behind the vallate papillæ, but are also present at the tip and margins. In this connexion the *anterior lingual glands* require special notice. They are situated on the under surface of the tip of the tongue (fig. 1141), one on each side of the frenulum, where they are covered by the mucous membrane and by a fasciculus of muscular fibres derived from the Styloglossus and Longitudinalis inferior. They are from 12 mm. to 20 mm. long, and about 8 mm. broad; each consists of mucous and serous alveoli, and opens by three or four ducts on the under surface of the tip of the tongue.

The *serous glands* occur in the neighbourhood of the taste-buds, their ducts opening for the most part into the sulci of the vallate papillæ. These glands are racemose; the duct of each branches into several minute ducts, which end in alveoli lined by a single layer of more or less columnar epithelium. Their secretion is of a watery nature, and probably assists in distributing the substance to be tasted over the taste area (Ebner).

The *septum* of the tongue is a median fibrous partition which extends throughout the length of the organ, but does not quite reach the dorsum; it gives origin to the Transversus linguæ, and is well displayed in a coronal section of the tongue. Posteriorly it expands in a transverse direction and forms what is sometimes known as the *hyoglossal membrane*; this membrane connects the root of the tongue to the hyoid bone, and gives insertion to the inferior fibres of the Genioglossi.

Taste-buds are scattered over the mucous membrane of the mouth and tongue at irregular intervals. They occur especially in the sides of the vallate papillæ. They are described under the organs of the senses (p. 1154).

Vessels and Nerves.—The main *artery* of the tongue is the lingual branch of the external carotid artery, but the facial (external maxillary) and ascending pharyngeal arteries also give branches to it. The *veins* open into the internal jugular vein.

The *lymph vessels of the tongue* are described on p. 856.

The *sensory nerves of the tongue* are: (1) the lingual branch of the mandibular nerve, which is the nerve of ordinary sensibility for the anterior two-thirds of the tongue; (2) the chorda tympani branch of the facial nerve, which runs in the sheath of the lingual nerve, and is generally regarded as the nerve of taste for the anterior two-thirds; this nerve is derived from the sensory root of the facial (nervus intermedius); (3) the lingual branch of the glossopharyngeal nerve, which is distributed to the mucous membrane at the base and sides of the tongue, and to the vallate papillæ, and is the nerve of taste and of general sensibility for this region; (4) the superior laryngeal nerve, which sends some fine branches to the part near the epiglottis.

Applied Anatomy.—Congenital cysts and fistulæ may develop from persistent remains of thyroglossal duct (p. 165).

It is the attachment of the Genioglossi to the genial tubercles on the inner surface of the symphysis of the mandible which prevents the tongue from falling back and obstructing respiration, and, therefore, anæsthetists always pull forward the mandible and so get the full benefit of this connexion.

A consideration of the lymph vessels of the tongue (p. 856) will indicate the extent of the operation necessary for the removal of cancer of the tongue.

The Oropharyngeal Isthmus (fig. 1141)

The aperture by which the mouth communicates with the pharynx is called the *oropharyngeal isthmus.* Above, it is bounded by the soft palate; below, by the dorsum of the tongue; and, at the sides, by the palatoglossal arches.

The *palatoglossal arch* runs downwards, laterally and forwards on each side from the inferior surface of the soft palate to the side of the tongue, and is formed by the projection of the Palatoglossus (p. 1265) with its covering mucous membrane. The approximation of the arches, which helps to shut off the mouth from the oral part of the pharynx, plays an important part in the mechanism of deglutition (p. 1299).

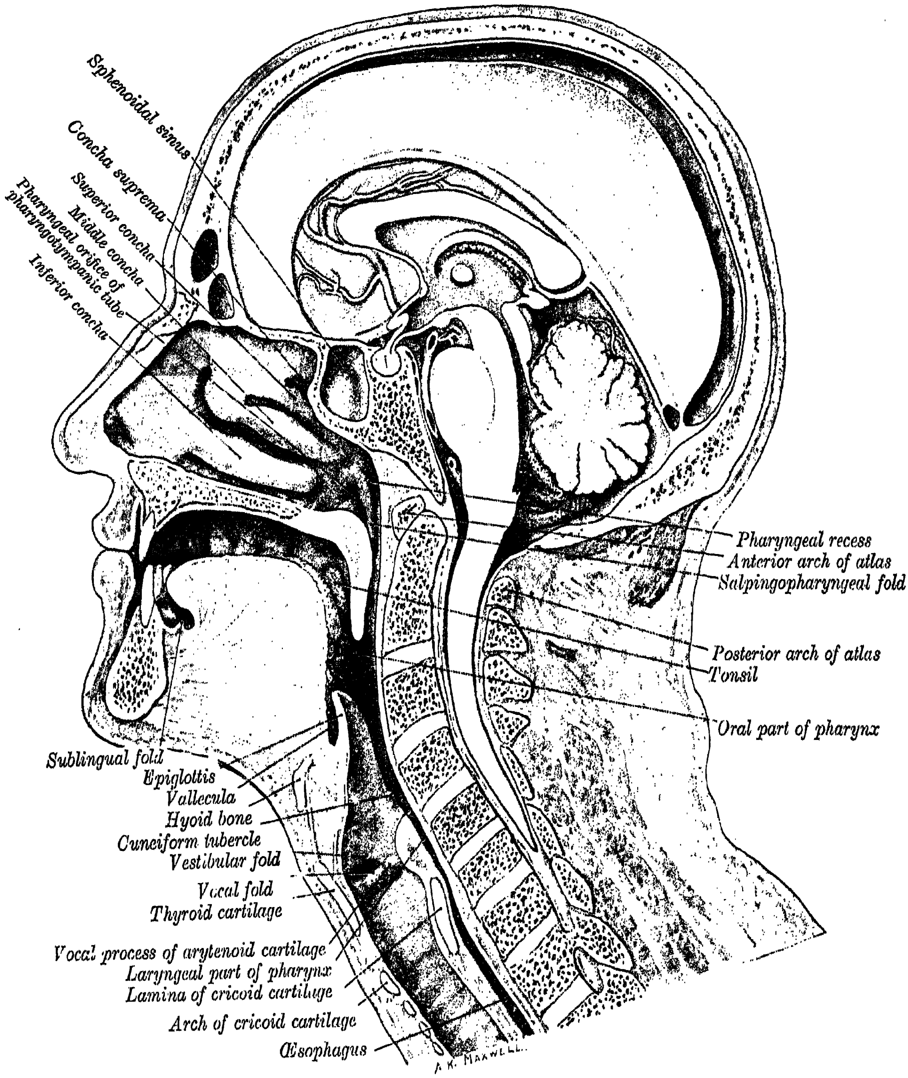
The Pharynx (figs. 1147, 1150, 1152)

The **pharynx** is the part of the digestive tube which is placed behind the nasal cavities, the mouth and the larynx. It is a musculomembranous tube, from 12 to 14 cm. long, which extends from the under surface of the skull to the sixth cervical vertebra opposite the lower border of the cricoid cartilage. Its width is greatest at its uppermost part, where it measures 3·5 cm.; at the junction of the pharynx with the œsophagus it is reduced to about 1·5 cm. The pharynx is limited, *above,* by the body of the sphenoid bone and the basilar part of the occipital bone; *below,* it is continuous with the œsophagus; *behind,* it is separated by loose areolar tissue from the cervical portion of the vertebral column and the prevertebral fascia covering the Longus cervicis (Longus colli) and Longus capitis muscles; *in front,* it opens into the nasal cavity, the mouth and the larynx, and therefore its anterior wall is incomplete. It is attached from above downwards, on each side, to the medial pterygoid plate, pterygomandibular ligament, mandible, tongue, hyoid bone, and thyroid and cricoid cartilages; *laterally,* it communicates with the tympanic cavities through the pharyngotympanic (auditory) tubes, and is in relation with the styloid processes and their muscles, the common and external carotid arteries, and some of the branches of the latter artery. The pharynx consists of three parts: nasal, oral and laryngeal (fig. 1147).

The **nasal part of the pharynx** lies behind the nose and above the level of the soft palate. With the exception of the soft palate its walls are immovable, and consequently its cavity is never obliterated; in this respect it differs from the oral and laryngeal parts. *In front* (fig. 1147) it communicates with the nasal cavity through the posterior apertures of the nose; these measure about 25 mm. vertically, and 12·5 mm. transversely, and are separated by the posterior edge of the nasal septum. Between the free edge of the soft palate and the posterior wall of the pharynx the nasal and oral parts of the pharynx communicate through an opening, termed the *pharyngeal isthmus;* in the act of swallowing this opening is closed by the elevation of the soft palate and the contraction of the Palatopharyngeal sphincter (p. 1298). The *lateral wall,* on each side, presents the *pharyngeal opening of the pharyngotympanic* (*auditory*) *tube,* which lies behind and a little below the posterior end of the inferior nasal concha. Somewhat triangular in shape, this opening is bounded behind by the *tubal elevation* [torus tubarius], a firm prominence which is provided by the underlying pharyngeal end of the cartilage of the pharyngotympanic tube (p. 1199). A vertical fold of mucous membrane, termed the *salpingopharyngeal fold,* stretches from the lower part of the tubal elevation downwards to the wall of the pharynx; it contains the *Salpingopharyngeus* muscle. A second and smaller fold, termed the *salpingopalatine fold,* stretches from the upper part of the elevation to the palate. Behind the tubal elevation the mucous membrane

lines a recess of variable depth, termed the *pharyngeal recess.* The *roof* and *posterior wall* form a continuous sloping surface which inclines downwards and backwards. It is supported by the posterior part of the body of the sphenoid bone, the basilar part of the occipital bone and the anterior arch of the atlas. A collection of lymphoid tissue, best developed in children, lies in the mucous

FIG. 1147.—A sagittal section through the nose, mouth, pharynx and larynx.



membrane of the upper part of this surface and is known as the *nasopharyngeal tonsil.*

The nasopharyngeal tonsil is visible to the naked eye during the later months of fœtal life and usually increases in size up to the age of six or seven years, after which it not infrequently begins to atrophy. In a child of eighteen months it forms a triangular prominence the apex of which is near the nasal septum, and the base at the junction of the roof and posterior wall of the nasal part of the pharynx. The prominence consists of a number of folds which radiate forwards and laterally from a median recess, termed the *pharyngeal bursa.* The folds consist mainly of diffuse lymphoid tissue, but there are also some deeply

placed mucous glands. The pharyngeal bursa lies close to the base of the naso-pharyngeal tonsil and presents the appearance of a blind recess.*

The **oral part of the pharynx** reaches from the soft palate to the upper border of the epiglottis. It opens anteriorly, through the oropharyngeal isthmus, into the mouth. Its lateral wall presents the palatopharyngeal arch and the tonsil. Posteriorly, it is supported by the body of the second cervical vertebra and the upper part of the body of the third.

The *palatopharyngeal arch* (pharyngopalatine arch) lies behind and projects farther towards the median plane than the palatoglossal arch ; it runs downwards, laterally and backwards from the margin of the uvula to the side of the pharynx, and is formed by the projection of the Palatopharyngeus (Pharyngopalatinus) (p. 1265), covered with mucous membrane. On each side the palatopharyngeal and palatoglossal arches are separated below by a triangular recess, in which the tonsil is lodged.

The **tonsils** (palatine tonsils) (fig. 1142) are two masses of lymphoid tissue, situated in the lateral walls of the oral part of the pharynx. Each tonsil is placed in the triangular recess between the diverging palatoglossal and palatopharyngeal arches. Its medial surface is free and forms a conspicuous projection into the pharynx during childhood, but the size of this projection is not a true indication of the size of the organ. Its deep, or lateral, aspect extends upwards, downwards and forwards beyond the limits of the medial surface and is imbedded below the level of the mucous membrane. Inferiorly, it extends into the dorsum of the tongue ; superiorly, it invades the soft palate ; and, anteriorly, it may extend for some distance deep to the palatoglossal arch. The tonsil is variable in size and is frequently the seat of inflammatory changes involving hypertrophy. As a result it is difficult to decide which of the many varieties encountered is to be regarded as normal. In late fœtal life, a free fold of mucous membrane, which extends backwards from the palatoglossal arch, covers the anterior-inferior part of the tonsil and is termed the *plica triangularis*. In the child this fold is usually invaded by lymphoid tissue and becomes incorporated in the tonsil ; it is only rarely present as a small, free fold which extends backwards from the lower part of the palatoglossal arch.

The upper part of the tonsil contains a deep *intratonsillar cleft*, frequently and erroneously termed the *supratonsillar fossa*. This cleft does not lie above the tonsil, but actually in its substance, and its upper wall contains a quantity of lymphoid tissue which may reach a large size and extend into the soft palate. After puberty the imbedded part of the tonsil diminishes considerably in size and the projecting medial surface becomes flattened and much less prominent.

The *free surface* of the tonsil presents from twelve to fifteen orifices leading into small recesses, termed the *tonsillar pits*, from which numerous follicles branch out into the tonsillar substance.

The *lateral* or *deep surface* is covered by a layer of fibrous tissue, termed the *capsule*. In most of its extent the tonsil and its capsule can easily be separated from the muscular wall of the pharynx, which is formed in this situation by the Constrictor pharyngis superior with the Styloglossus on its lateral side (fig. 1150). At its antero-inferior part the capsule is firmly connected to the side of the tongue, and behind this point it receives the insertion of some muscular fibres. In the latter situation the tonsillar artery, which is a branch of the facial (external maxillary) artery, pierces the Constrictor pharyngis superior and at once enters the tonsil, accompanied by two venæ comitantes. An important, and sometimes large, palatine vein descends from the soft palate across the lateral aspect of the capsule of the tonsil before piercing the pharyngeal wall. It is this vessel which is responsible for the excessive venous hæmorrhage sometimes encountered in excision of the tonsil.† The muscular wall of the sinus tonsillaris separates the tonsil from the ascending palatine artery and, occasionally, from the facial artery itself (p. 707). The internal carotid artery lies 2·5 cm. behind and lateral to the tonsil.

* J. Symington, *British Medical Journal*, Oct. 15, 1910.

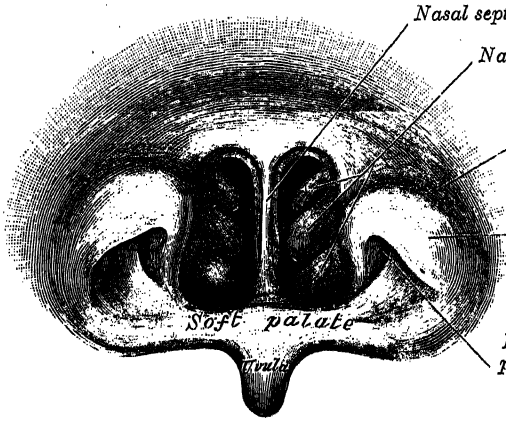
† D. Browne, *Journal of Anatomy*, vol. lxiii., 1928.

The tonsils form part of a circular band of lymphoid tissue which guards the opening into the digestive and respiratory tubes. The anterior and lower part of the ring is formed by the lingual tonsil; the lateral portions consist of the tonsils and the lymphoid collections in the vicinity of the pharyngotympanic (auditory) tubes; the ring is completed behind and above by the nasopharyngeal tonsil (p. 1291). Smaller collections of lymphoid tissue are found in the intervals between these main masses.

Structure.—The pits of the tonsil are lined by stratified squamous epithelium, which is continuous with that of the mucous membrane of the pharynx, and is invaded by numerous lymph-corpuscles; probably some of the latter pass into the mouth and form the so-called salivary corpuscles. The tonsil consists of lymphoid tissue which is arranged in nodules or follicles. The lymphocytes are less closely packed in the centre of each nodule, which is described as a *germ-centre*, because multiplication of the corpuscles goes on in this situation. A close plexus of lymph vessels surrounds each follicle and from it the lymph vessels pass to the upper deep cervical lymph-glands, and especially to the jugulodigastric lymph gland (p. 856).

Vessels and Nerves.—The chief *artery* supplying the tonsil is the tonsillar artery, a branch of the facial artery. In addition, it may receive occasional twigs from the dorsalis

Fig. 1148.—The front of the nasal part of the pharynx, as seen with the laryngoscope.



linguæ branches of the lingual artery, the ascending palatine branch of the facial artery, the ascending pharyngeal artery, and the greater palatine branch of the (internal) maxillary artery.

One or more *veins* leave the lower part of the deep aspect of the tonsil and at once pierce the superior constrictor muscle to join the pharyngeal or common facial veins.

The *nerves* are derived from the sphenopalatine ganglion, through the lesser palatine nerves, and from the glossopharyngeal nerve.

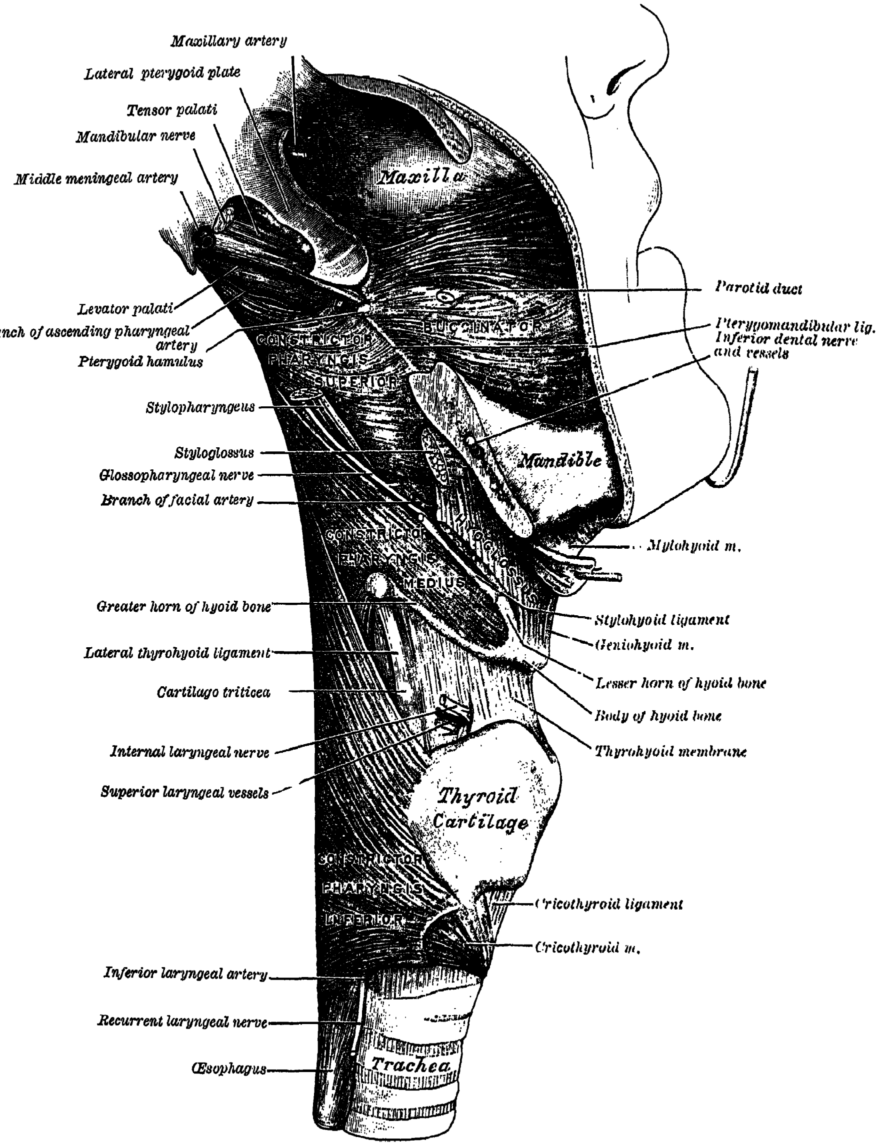
Applied Anatomy.—The tonsils can be inspected easily by instructing the patient to throw the head back and open his mouth widely, the tongue at the same time being depressed by a spatula or tongue-depressor. The normal tonsil should not project beyond the plane of the palatoglossal arch. They are prone to become enlarged, especially in tuberculous children; and when much increased in size they cause great trouble owing to obstruction to respiration and deglutition.

The laryngeal part of the pharynx reaches from the upper border of the epiglottis to the lower border of the cricoid cartilage, where it is continuous with the œsophagus. Its anterior wall presents, from above downwards, the inlet of the larynx (p. 1233), the posterior surfaces of the arytenoid cartilages and the posterior aspect of the cricoid cartilage. A small recess, termed the *piriform fossa*, lies on each side of the laryngeal orifice; it is bounded, medially, by the aryepiglottic fold and, laterally, by the thyroid cartilage and the thyrohyoid membrane. Posteriorly the laryngeal part of the pharynx is supported by the bodies of the third (lower part), fourth, fifth and sixth (upper part) cervical vertebrae.

Structure.—The pharynx is composed, from within outwards, of three coats; mucous, fibrous and muscular, the last being covered by the thin buccopharyngeal fascia, which covers the outer surface of the Constrictor muscles and extends forwards over the pterygomandibular ligament on to the Buccinator muscle.

The *mucous coat* is continuous with that of the pharyngotympanic tubes, nasal cavity, mouth and larynx. In the nasal part of the pharynx its epithelium is columnar and ciliated;

FIG. 1149.—The Buccinator and the muscles of the pharynx.



in the oral and laryngeal portions it is stratified squamous. Between the region covered by ciliated columnar epithelium and that covered by squamous epithelium, there is a narrow intermediate zone where the epithelium is cubical, and the cilia are imperfect or absent. Superiorly, this zone lies near the nasal septum: laterally it passes over the orifice of the pharyngotympanic tube and inclines backwards at the union of the soft palate with the lateral wall. Racemose glands are found beneath the mucous membrane, and are especially numerous at the upper part of the pharynx around the orifices of the pharyngotympanic tubes.

The *fibrous coat* is situated between the mucous and muscular layers. It is thick above (pharyngobasilar fascia) where the muscular fibres are wanting, and is firmly connected to the basilar portion of the occipital bone and the petrous portions of the temporal bones.

As it descends it diminishes in thickness, and is gradually lost. It is strengthened posteriorly by a strong fibrous band, which is attached above to the pharyngeal tubercle on the under surface of the basilar portion of the occipital bone, and passes downwards as a median raphe which gives attachment to the Constrictor muscles (fig. 1152).

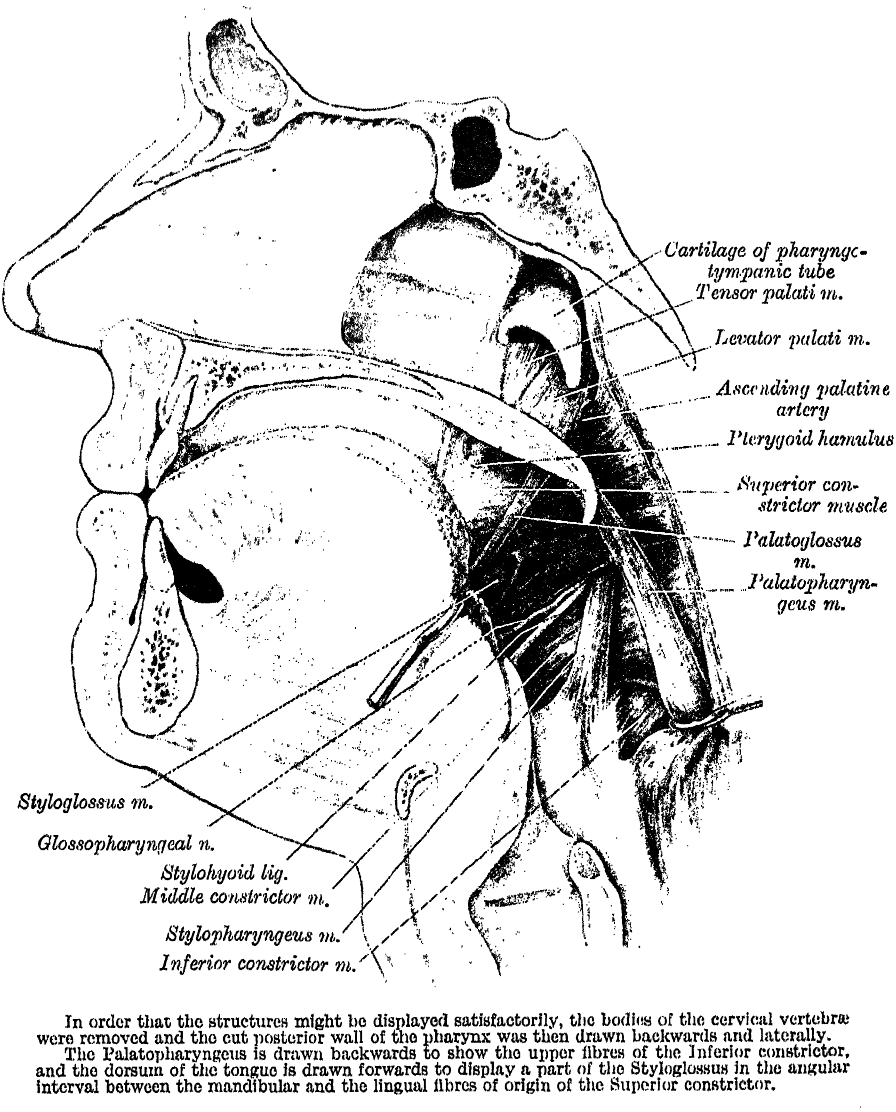
The *muscular coat* consists of the muscles of the pharynx.

The muscles of the pharynx (figs. 1146, 1149-52) are:

Constrictor pharyngis inferior.	Stylopharyngeus.
Constrictor pharyngis medius.	Salpingopharyngeus.
Constrictor pharyngis superior.	Palatopharyngeus.*

The **Constrictor pharyngis inferior** is the thickest of the constrictors. It arises from the cricoid cartilage in the interval between the origin of the Crico-

FIG. 1150.—Median sagittal section of the head, showing a dissection of the interior of the pharynx, after the removal of the mucous membrane.



In order that the structures might be displayed satisfactorily, the bodies of the cervical vertebræ were removed and the cut posterior wall of the pharynx was then drawn backwards and laterally. The Palatopharyngeus is drawn backwards to show the upper fibres of the Inferior constrictor, and the dorsum of the tongue is drawn forwards to display a part of the Styloglossus in the angular interval between the mandibular and the lingual fibres of origin of the Superior constrictor.

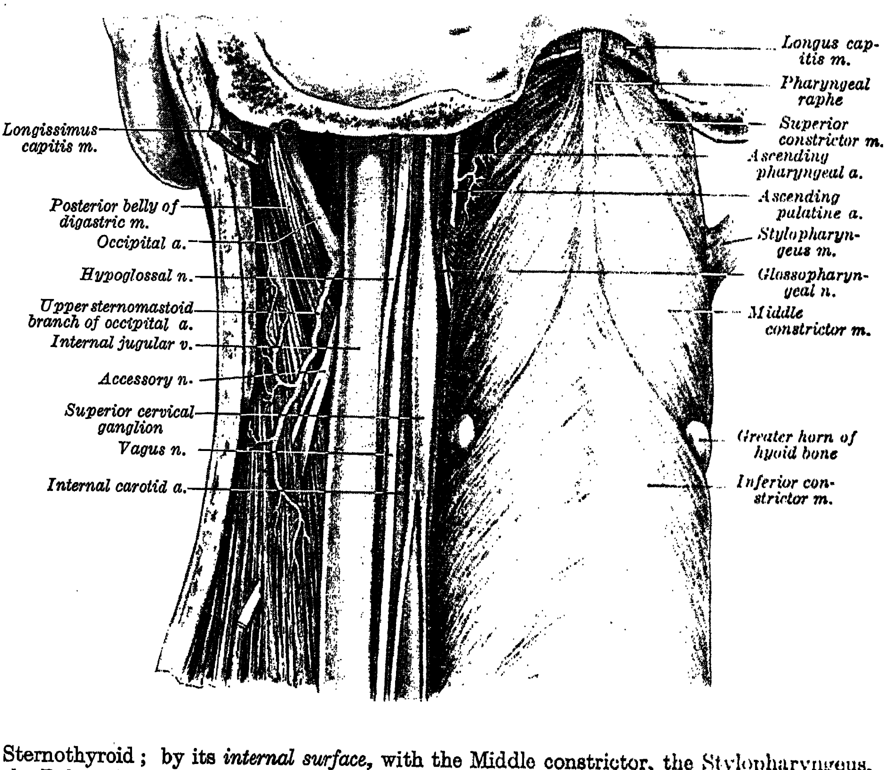
thyroid in front, and the articular facet for the inferior horn of the thyroid cartilage behind (*Cricopharyngeus*). It also arises from the oblique line of the lamina of the thyroid cartilage, from a strip of the surface of the lamina behind this line, from a fine tendinous band, which is thrown across the cricothyroid

* The Palatopharyngeus is described with the muscles of the palate (p. 1265).

muscle from the inferior thyroid tubercle to the cricoid cartilage (fig. 1094), and, by a small slip, from the inferior horn (*Thyreopharyngeus*). The fibres spread backwards and medially, and are inserted with the muscle of the opposite side into a fibrous raphe in the posterior median line of the pharynx. The inferior fibres, which are horizontal, are continuous with the circular fibres of the œsophagus and surround the narrowest part of the pharynx; the rest ascend obliquely, and overlap the Middle constrictor.

Relations.—The Inferior constrictor is covered with the buccopharyngeal fascia, which surrounds the entire pharynx. *Behind*, the muscle is in relation with the prevertebral fascia and muscles; *laterally*, with the thyroid gland, the common carotid artery, and the

FIG. 1151.—The pharynx, exposed from behind.



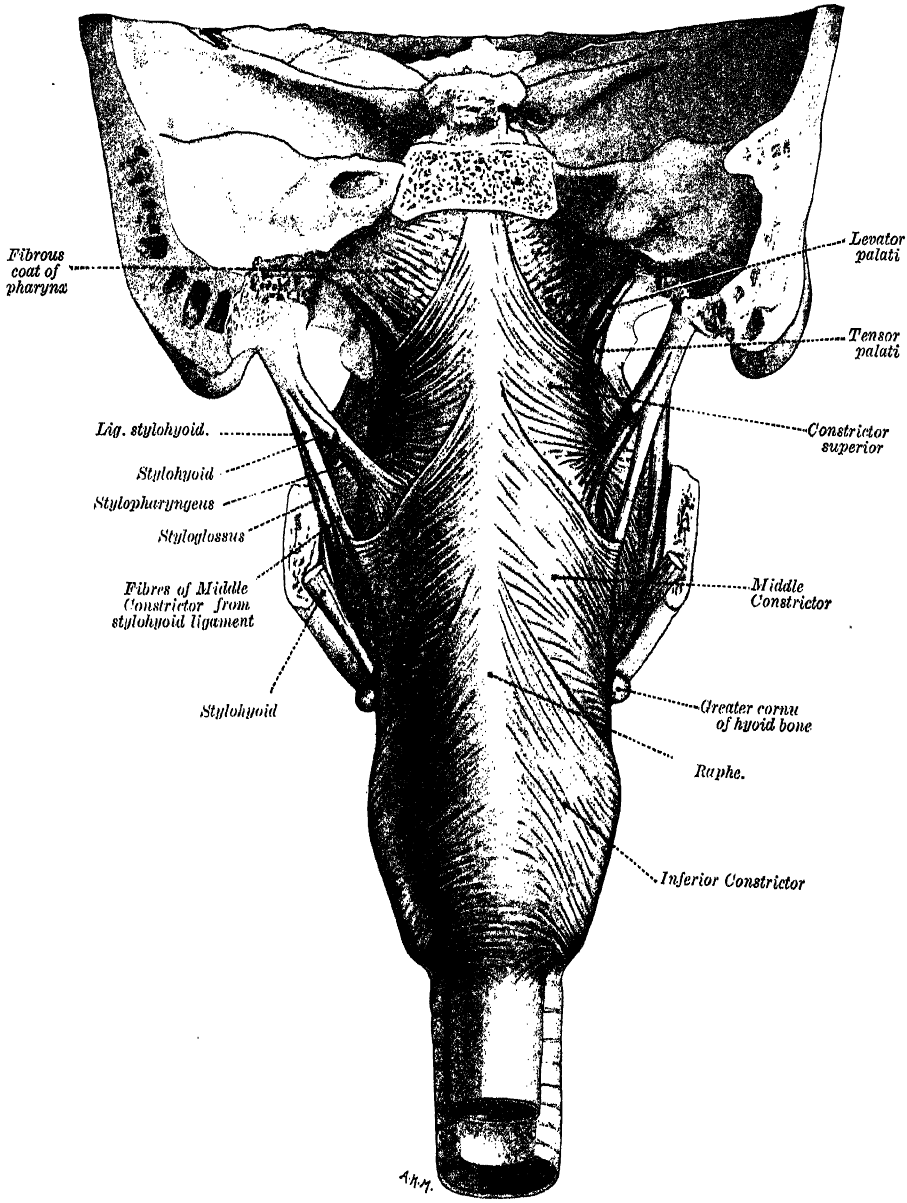
Sternothyroid; by its *internal surface*, with the Middle constrictor, the Stylopharyngeus, the Palatopharyngeus and the pharyngeal aponeurosis. The internal laryngeal nerve and the laryngeal branch of the superior thyroid artery run near the upper border, and the recurrent laryngeal nerve and the laryngeal branch of the inferior thyroid artery ascend deep to its lower border, before they enter the larynx.

The **Constrictor pharyngis medius** is a fan-shaped muscle which arises from the lesser horn and from the whole length of the upper border of the greater horn of the hyoid bone, and from the lower part of the stylohyoid ligament. The lower fibres descend deep to the Inferior constrictor, as far as the inferior end of the pharynx, the middle fibres pass transversely, and the upper fibres ascend and overlap the Superior constrictor. It is inserted, with the muscle of the opposite side, into the posterior median fibrous raphe.

Relations.—The Middle constrictor is separated from the Superior constrictor by a small interval, through which pass the glossopharyngeal nerve and the Stylopharyngeus muscle; and from the Inferior constrictor by the internal laryngeal nerve and laryngeal branch of the superior thyroid artery. *Behind*, it is related to the prevertebral fascia, the Longus cervicis and the Longus capitis. *Laterally*, it is in relation with the carotid vessels, the pharyngeal plexus of nerves and some lymph glands. Near its origin it is covered with the Hyoglossus, from which it is separated by the lingual vessels. Its *internal surface* lies upon the Superior constrictor, the Stylopharyngeus, the Palatopharyngeus and the pharyngeal aponeurosis.

The **Constrictor pharyngis superior** is a quadrilateral muscle, thinner and paler than the other two. It arises from the pterygoid hamulus, and sometimes from the adjoining part of the posterior margin of the medial pterygoid plate, from the pterygomandibular ligament, from the posterior end of the mylohyoid line on the inner surface of the mandible, and by a few fibres from the side of

FIG. 1152.—The muscles of the pharynx; posterior view. (From Quain's *Anatomy*, XI. Ed.)



the tongue (fig. 1150). The fibres curve backwards to be inserted into the median raphe, being also prolonged by means of an aponeurosis to the pharyngeal tubercle on the basilar part of the occipital bone. The superior fibres arch beneath the Levator palati and the pharyngotympanic (auditory) tube. An interval exists between the upper border of the muscle and the base of the skull to give passage to the pharyngotympanic (auditory tube). It is bounded in front by the medial pterygoid plate and is closed by the pharyngobasilar fascia (p. 1294).

A constant band of muscle fibres arises from the anterior and lateral part

of the palatine aponeurosis and sweeps backwards, lateral to the Levator palati, to blend with the inner surface of the Superior constrictor muscle near its upper border. Whillis * has termed this band the *Palatopharyngeal sphincter* and has pointed out that, when the soft palate is raised, it produces a rounded ridge on the pharyngeal wall. These fibres are much hypertrophied in cases of complete cleft palate.

Relations.—The Superior constrictor muscle is in relation by its *external surface* with the prevertebral fascia and muscles, the ascending pharyngeal artery and pharyngeal venous plexus, the glossopharyngeal and lingual nerves, the Styloglossus, Constrictor pharyngis medius and Pterygoideus medialis, the stylohyoid ligament and the Stylopharyngeus. The internal carotid artery, the sympathetic trunk, the hypoglossal nerve, the internal jugular vein and the styloid process are more distant relations. By its *internal surface* it is in relation with the Palatopharyngeus, the capsule of the tonsil, and the pharyngeal aponeurosis. Its *upper border* is separated from the base of the skull by a crescentic interval in which the Levator palati, the Tensor palati and the pharyngotympanic tube are situated. Its lower border is separated from the Middle constrictor by the Stylopharyngeus. *In front* it is separated from the Buccinator by the pterygomandibular ligament.

Nerve-supply.—The Constrictors of the pharynx are supplied by the pharyngeal plexus (p. 1069). In addition the Inferior constrictor receives branches from the external and recurrent laryngeal nerves.

The **Stylopharyngeus** (figs. 1146, 1151) is a long, slender muscle which is cylindrical above and flattened below. It arises from the medial side of the base of the styloid process of the temporal bone, descends along the side of the pharynx, passes between the Superior and the Middle constrictors, and spreads out beneath the mucous membrane. Some of its fibres are lost in the constrictor muscles and in the pharyngo-epiglottic fold, while others are inserted with the Palatopharyngeus into the posterior border of the thyroid cartilage. The glossopharyngeal nerve winds round the lateral side of the Stylopharyngeus muscle and passes through the interval between the Superior and the Middle constrictors to reach the tongue.

Nerve-supply.—The Stylopharyngeus is supplied by a branch from the glossopharyngeal nerve.

The **Salpingopharyngeus** (fig. 1118) arises from the inferior part of the cartilage of the pharyngotympanic (auditory) tube near its pharyngeal opening; it passes downwards and blends with the Palatopharyngeus.

Nerve-supply.—The Salpingopharyngeus is supplied by the pharyngeal plexus.

Actions.—The Salpingopharyngeus raises the upper part of the lateral wall of the pharynx, i.e. the part above the attachment of the Stylopharyngeus.

MOVEMENTS OF THE SOFT PALATE

The movements of the soft palate play an important part in deglutition, in speech and in the act of blowing, and involve a greater or lesser degree of closure of the pharyngeal isthmus, necessitated by these acts. The closure is maximal in blowing out through the mouth, when it is essential to prevent entirely the escape of air through the nose. In deglutition closure of the pharyngeal isthmus prevents the food from passing into the nasal part of the pharynx, whilst in speech the closure is maximal in the production of the explosive consonants.

Closure of the isthmus is brought about in the following way. The two Levatores palati pull the soft palate upwards and backwards towards the posterior pharyngeal wall. Coincident with this movement the fibres of the Palatopharyngeal sphincter raise a rounded ridge on the posterior pharyngeal wall, which meets the nasal surface of the soft palate over a considerable area, and it is at the upper limit of this area of contact that the mucous membrane on the upper surface of the palate changes from the respiratory to the pharyngeal type.

The Tensor palati is active in deglutition rather than in speech, and by producing a localised depression of the palate (p. 1265) squeezes the bolus against the tongue and so helps to project it through the oral pharynx.

* J. Whillis, *Journal of Anatomy*, vol. lxv., 1930.

The Mechanism of Deglutition

The first stage of the act of swallowing, or deglutition, is voluntary in character. The anterior part of the tongue is raised and pressed against the hard palate, the movement commencing at the tip of the tongue and spreading backwards rapidly. By this mechanism a bolus placed on the tongue behind the tip passes backwards to the posterior part of the mouth. The movements of the tongue are effected by the intrinsic muscles, especially the Longitudinales superiores and the Transversi linguæ. At the same time the hyoid bone moves forwards and upwards a little and becomes fixed owing to contraction of the Geniohyoid, Mylohyoid, Digastric and Stylohyoid muscles. By elevation of the posterior part of the tongue, which is drawn upwards and backwards by the Styloglossi, and by the approximation of the palatoglossal arches, caused by the contraction of the Palatoglossi, the bolus is now passed through the oropharyngeal isthmus into the oral part of the pharynx and the second, or involuntary, stage of the act of swallowing begins.

In the second stage, the soft palate is elevated (by the Levator muscles) and tightened (by the Tensor muscles). In addition it is closely and firmly approximated to the posterior pharyngeal wall by the contraction of the Palatopharyngeal sphincter (p. 1298) and the upper fibres of the Superior constrictor muscle. The pharyngeal isthmus is tightly closed and the bolus is prevented from passing upwards. At the same time the larynx is drawn upwards behind the hyoid bone and the pharynx ascends with it. This upward displacement is brought about by the Stylopharyngeus, Thyrohyoid and Palatopharyngeus muscles. Simultaneously the aryepiglottic folds are approximated and the arytenoid cartilages are drawn upwards and forwards by the contraction of the Aryepiglottic, Oblique arytenoid, Thyro-arytenoid and Thyroepiglottic muscles. Provision is thus made to prevent the bolus from entering the larynx. Partly under the influence of gravity—when the body is in the erect or sitting posture—and partly urged onwards by the successive contractions of the Superior and Middle constrictor muscles, the bolus slips over the posterior aspect of the epiglottis, the closed inlet of the larynx and the posterior surfaces of the arytenoid cartilages to gain the lowest part of the pharynx. During this stage its passage is facilitated by the action of the Palatopharyngei, which shorten the pharynx and pull it upwards. These two muscles, when contracting, convert the surface of the posterior pharyngeal wall into an inclined plane directed downwards and backwards and on its under surface the bolus descends.

The last stage in the act is effected by the Inferior constrictor muscle, which passes the bolus onwards into the œsophagus.

These stages follow one another in rapid succession, but it is not difficult for the student to satisfy himself, by palpation of the body of the hyoid bone and the laryngeal prominence during the act, that elevation and forward movement of the hyoid bone precede elevation of the larynx and that the amount of upward movement of the thyroid cartilage is considerable.

Applied Anatomy.—In young children the presence of adenoid growths in the nose and nasopharynx, with or without enlargement of the tonsils, produces a characteristic deformity of the face, the " adenoid facies," by obstructing respiration through the nose and making mouth-breathing more or less obligatory. As the child has to keep its mouth open in order to breathe, the bony palate and alveolar arch are habitually out of contact with the dorsum of the tongue ; lacking its pressure, they develop with an abnormally high arch and forward projection. Thus the hard palate becomes narrowed laterally, and the projecting alveolar processes afford insufficient room for the permanent teeth, which appear crowded, irregularly set, and overhang those in the lower jaw. The facial surfaces of the maxillæ become pinched together, with narrowing of the nasal fossæ and maxillary air-sinuses. The nose itself shows abnormality in shape of two chief types ; (1) The bridge remaining normal, the apex looks thin and pinched because the alæ fall inwards from disuse of the dilator muscles, and the nares become elongated, narrow, and barely capable of voluntary dilatation ; there is often a depression in the region of the lateral alar cartilage. (2) Less commonly the bones forming the bridge of the nose are pressed apart by the underlying adenoid growths, making it appear thicker and broader than normal ; the dilators of the nares atrophy from disuse, and the nares look unduly small and rounded. In all cases of adenoids the upper lip is drawn up, still further exposing the projecting

front upper teeth. The face is lengthened by dropping of the lower jaw; the whole expression of the child is highly characteristic, suggesting vacuity and inattention, the latter being due to the deafness so often associated with nasal obstruction and caused by blocking of the pharyngeal openings of the pharyngotympanic tubes.

The Œsophagus (fig. 1153). (Pl. XIV.)

Fig. 1153.—The œsophagus.

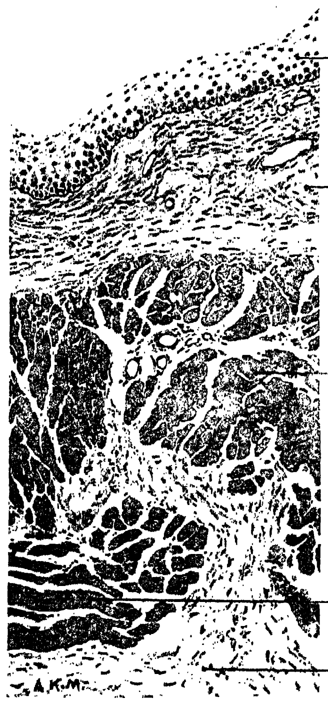
The œsophagus, or **gullet**, is a muscular canal, from 23 cm. to 25 cm. long, extending from the pharynx to the stomach. It begins in the neck at the lower border of the cricoid cartilage, opposite the sixth cervical vertebra, where it is continuous with the lower end of the pharynx. It descends along the front of the vertebral column, through the superior and posterior parts of the mediastinum, pierces the Diaphragm opposite the tenth thoracic vertebra, and ends at the cardiac orifice of the stomach at the level of the eleventh thoracic vertebra. The general direction of the œsophagus is vertical; but it presents two slight curves in its course. At its commencement it is placed in the median plane; but it inclines to the left side as far as the root of the neck, gradually passes again to the median plane, which it reaches at the level of the fifth thoracic vertebra, and again deviates to the left as it passes forwards to the œsophageal opening in the Diaphragm. The œsophagus presents also anteroposterior flexures corresponding to the curvatures of the cervical and thoracic portions of the vertebral column. It is the narrowest part of the digestive tube, and is constricted (*a*) at its commencement, (*b*) where it is crossed by the left bronchus, and (*c*) where it pierces the Diaphragm.

Relations.—The **cervical part** of the œsophagus (fig. 1098) is in relation, *in front*, with the trachea, and at the lower part of the neck, where it projects to the left side, with the left lobe of the thyroid gland; *behind*, it lies on the vertebral column and Longus cervicis muscles; *laterally*, it is in relation with the common carotid arteries (especially the left), and with parts of the lobes of the thyroid gland; the recurrent laryngeal nerves ascend, one on each side, in the groove between it and the trachea; the thoracic duct ascends for a short distance along its left edge.

The **thoracic part** of the œsophagus (figs. 1098-99, 1106-07, 1110, 1153) is at first situated in the superior mediastinum between the trachea and the

vertebral column, a little to the left of the median plane. It passes behind and to the right of the aortic arch and descends in the posterior mediastinum along the right side of the descending thoracic aorta. Below, as it inclines to the left, it crosses in front of the aorta, and enters the abdomen through the Diaphragm at the level of the tenth thoracic vertebra. It is in relation, *in front*, with the trachea, the left bronchus, the pericardium, and the Diaphragm; *behind*, it rests upon the vertebral column, the Longus cervicis muscles, the right posterior (aortic) intercostal arteries, the thoracic duct, the azygos vein and the terminal parts of the hemiazygos veins; and below, near the Diaphragm, upon the front of the aorta. In the posterior mediastinum an elongated recess of the right pleural sac intervenes between the œsophagus and the vena azygos and vertebral column. On its *left* side, in the superior mediastinum the terminal part of the aortic arch, the left subclavian artery, the thoracic duct, and left pleura are immediate relations, while the left recurrent laryngeal nerve runs upwards in the groove between it and the trachea; in the posterior mediastinum it is in relation with the descending thoracic aorta and the left pleura. On its *right* side it is related to the right pleura, the azygos vein intervening as it arches forwards above the right bronchus to join the superior vena cava. Below the roots of the lungs the vagus nerves descend in close contact with it, the right nerve chiefly behind, and the left chiefly in front of it; the two nerves unite to form a plexus around the tube (p. 1071).

Fig. 1154.—Longitudinal section through the upper part of the œsophagus.



In the lower part of the posterior mediastinum the thoracic duct lies behind and to the right of the œsophagus; higher up, it is placed behind it, and crossing to the left about the level of the fourth thoracic vertebra, is continued upwards on its left side.

The abdominal part of the œsophagus lies in the œsophageal groove on the posterior surface of the left lobe of the liver. It measures about 1·25 cm. in length, and is covered with peritoneum in front and on its left side. It is conical in shape, and curved sharply to the left, the base of the cone being continuous with the cardiac orifice of the stomach (fig. 1153).

Structure (fig. 1154).—The œsophagus has four coats: an external or fibrous, a muscular, a submucous or areolar, and an internal or mucous.

The *fibrous coat* consists of a layer of areolar tissue, containing many elastic fibres.

The *muscular coat* is composed of two layers of considerable thickness: an external of longitudinal and an internal of circular fibres.

The *longitudinal fibres* form a complete investment for nearly the whole of the œsophagus, but at the upper part of the back of the tube, at a point between 3 cm. and 4 cm. below the cricoid cartilage, they diverge from the median plane and form two longitudinal fasciculi which incline upwards and forwards to the front of the tube. Here they pass deep to the lower border of the Constrictor pharyngis inferior and end in a tendon which is attached to the upper part of the ridge on the posterior surface of the lamina of the cricoid cartilage (fig. 1095). The V-shaped interval between the diverging longitudinal fasciculi is filled by the circular fibres of the œsophagus, thinly covered below by some decussating longitudinal fibres, and above by the overlapping lower edge of the Constrictor pharyngis inferior.

Accessory slips of muscular fibres sometimes pass between the œsophagus and the left pleura, or between the œsophagus and the root of the left bronchus.

The *circular fibres* are continuous superiorly, on the posterior surface, with the Constrictor pharyngis inferior; anteriorly, the uppermost are inserted into the lateral margins of the tendon of the two longitudinal fasciculi.*

The muscular fibres in the upper part of the œsophagus are of a red colour, and consist chiefly of the striped variety; but in the lower part they consist for the most part of involuntary fibres.

The *areolar* or *submucous coat* connects loosely the mucous and muscular coats. It contains the larger blood-vessels and nerves, as well as mucous glands.

The *mucous coat* is thick, of a reddish colour above, and pale below. It is disposed in longitudinal folds (Pl. XIV), which disappear on distension of the tube. It consists of (1) a layer of stratified squamous epithelium, lining the tube, (2) a layer of connective tissue, papillæ from which project into the epithelium, and (3) the muscularis mucosæ, a layer of longitudinally arranged non-striped muscular fibres. At the commencement of the œsophagus the muscularis mucosæ is absent, or only represented by a few scattered bundles; lower down it forms a considerable stratum.

The *œsophageal glands* are small, compound racemose glands of the mucous type; they are lodged in the submucous tissue, and each opens into the tube by a long duct.

Vessels and Nerves.—The *arteries* supplying the œsophagus are derived from the inferior thyroid branch of the thyrocervical trunk, from the descending thoracic aorta, from the left gastric branch of the cœliac artery, and from the left (inferior) phrenic branch of the abdominal aorta. They have for the most part a longitudinal direction. The *veins* from the lower end of the œsophagus open into the left gastric vein, which is a tributary of the portal vein; those from the upper part join the azygos or the hemiazygos veins. The *lymph vessels* are described on p. 879.

The *nerves* are derived from the vagus nerves and from the sympathetic trunks; they form a plexus containing groups of ganglion-cells between the two layers of the muscular coat, and a second plexus in the submucous tissue.

Applied Anatomy.—The œsophagus may be obstructed by foreign bodies, and also by changes in its coats producing stricture, or by pressure on it from without by new growths or aneurysm, etc.

The mucous membrane of the œsophagus may become herniated through the muscular coat, giving rise to an œsophageal diverticulum. This condition occurs most frequently on the posterior surface of the beginning of the tube, where the wall is weakened by the absence of longitudinal muscle fibres (*vide supra*).

THE ABDOMEN

The **abdomen** is the largest cavity in the body. The roof of the cavity is formed by the Diaphragm, which extends as a dome over the abdomen, so that the cavity ascends into the bony thorax, reaching on the right side, in the mammary line, to the upper border of the fifth rib; on the left side it falls below this level by about 2·5 cm. The floor is formed by the muscles and fasciæ of the pelvic diaphragm (pp. 573 to 576).

In order to facilitate description the abdomen is artificially divided into two parts: an upper, larger part, the *abdomen proper*; and a lower, smaller part, the *pelvis*. These two parts are continuous with each other through the inlet of the true (lesser) pelvis.

The **abdomen proper** differs from the other cavities of the body in being bounded for the most part by muscles and fasciæ, so that its capacity and shape can vary according to the conditions of the viscera which it contains.

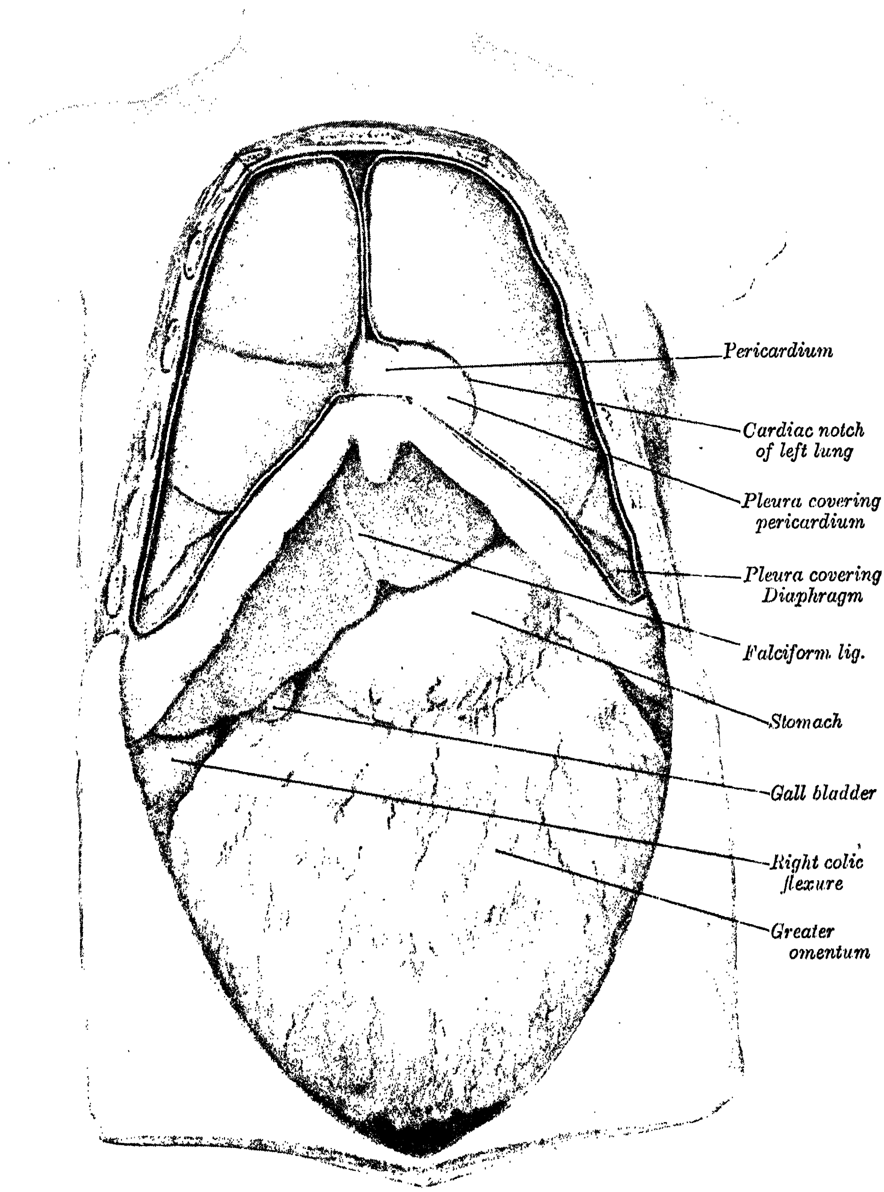
It is bounded *in front* and *at the sides* by the abdominal and Iliacus muscles, and the iliac bones; *behind*, by the lumbar part of the vertebral column and by the Psoas and Quadratus lumborum muscles; *above*, by the Diaphragm; *below*, by the plane of the inlet of the true pelvis. The muscles forming the boundaries of the cavity are lined upon their inner surfaces by a layer of fascia.

The abdomen contains the greater part of the digestive tube; it also contains the liver, pancreas, spleen, kidneys and suprarenal glands. Most of these structures, as well as the wall of the cavity in which they are contained, are more or less covered by an extensive and complicated serous membrane, termed the *peritoneum*.

* Williamina Abel, *Journal of Anatomy and Physiology*, vol. xlvii.

Regions.—For convenience of description of the viscera the abdomen is divided into nine regions by imaginary planes, two horizontal and two sagittal, passing through the cavity, the edges of the planes being indicated by lines drawn on the surface of the body (fig. 1156). The upper horizontal plane, or *transpyloric plane* (of Addison), is indicated by a line encircling the body at a

FIG. 1155.—A front view of the thoracic and abdominal viscera.

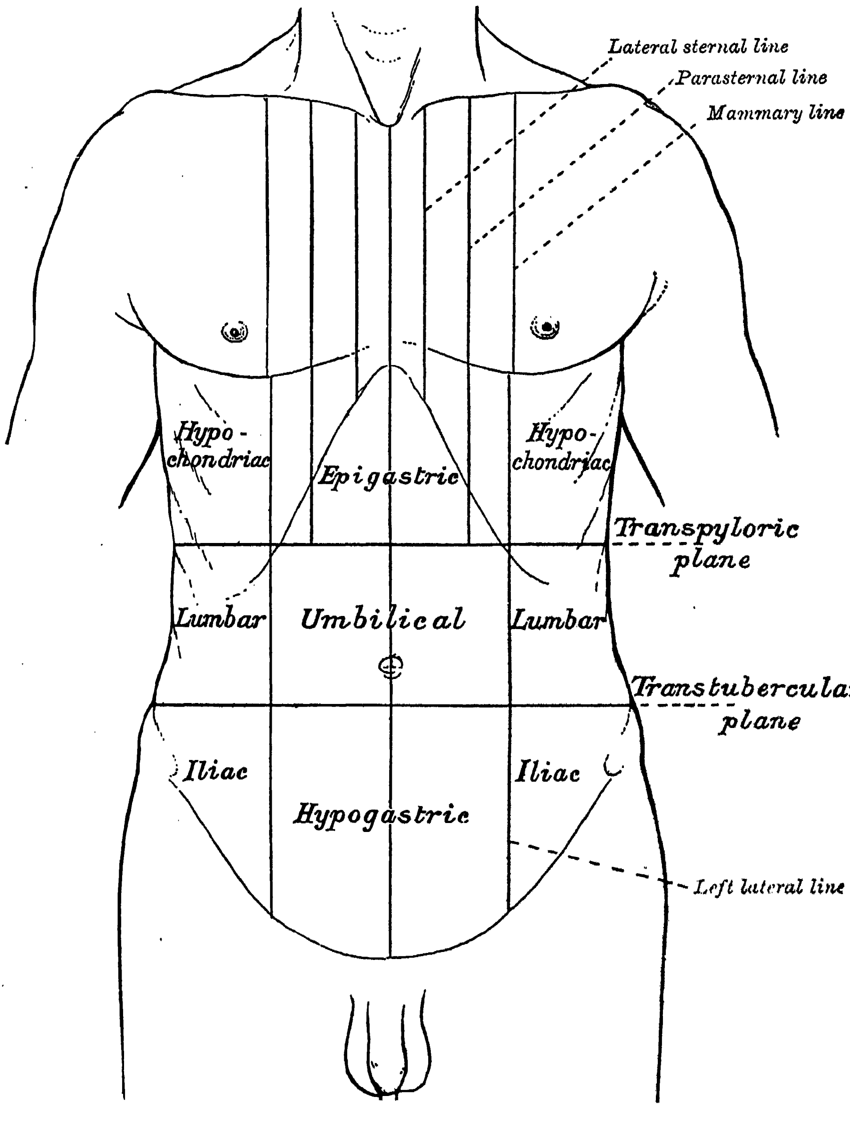


level midway between the suprasternal (jugular) notch and the symphysis pubis ; it cuts the front of the body of the first lumbar vertebra near its lower border. The lower horizontal plane is indicated by a line carried round the trunk at the level of the tubercle on the iliac crest (p. 368) and is termed the *transtubercular plane* ; it cuts the front of the body of the fifth lumbar vertebra near its upper border. By means of these planes the abdomen is cut into three zones ; each of these is further subdivided into three regions by the *right* and *left lateral planes*, which are indicated on the surface by lines drawn vertically

through points halfway between the anterior superior iliac spines and the symphysis pubis.*

The median region of the upper zone is the *epigastric*, and the lateral regions, the *right* and *left hypochondriac*. The median region of the middle zone is the *umbilical*, and the lateral regions are the *right* and *left lumbar*. The median

Fig. 1156.—The surface lines on the front of the thorax and abdomen.



region of the lower zone is the *hypogastric*, and the lateral regions are the *right* and *left iliac* or *inguinal* (fig. 1156).

A third horizontal plane is frequently utilised in describing the topography of the abdominal viscera. It is drawn through the body on a level with the most dependent parts of the tenth costal cartilages and is termed the *subcostal plane*. It cuts the front of the body of the third lumbar vertebra near its upper border. It is frequently utilised instead of the transpyloric plane for the purpose of dividing the abdomen into the regions named above.

The pelvis is that portion of the abdominal cavity which lies below and behind a plane passing through the promontory of the sacrum, the arcuate

* D. J. Cunningham, *Journal of Anatomy and Physiology*, vols. xxxiii., xxxiv., xxxv.

lines of the hip-bones, and the pubic crest; it contains the urinary bladder, the pelvic colon, the rectum, a few coils of the small intestine, and some of the generative organs.

When the anterior abdominal wall is removed (fig. 1155), the viscera are partly exposed as follows: above and to the right side the liver is visible, situated chiefly under the shelter of the right ribs and their cartilages, but extending across the median plane, and reaching for some distance below the level of the xiphoid process. The stomach is exposed in the angle between the left costal margin and the lower border of the liver. From its lower border an apron-like fold of peritoneum, termed the *greater omentum*, descends for a varying distance, and obscures the other viscera to a greater or lesser extent. Below the greater omentum, however, some of the coils of the small intestine can generally be seen, while in the right iliac region the cæcum, and in the left iliac region the lower portion of the descending colon, are partly exposed. The urinary bladder occupies the anterior part of the pelvis, and, if distended, projects above the symphysis pubis; the rectum is placed in the concavity of the sacrum, but is usually hidden by coils of the small intestine. The pelvic colon may lie between the rectum and the bladder.

When the stomach is followed from left to right it is seen to be continuous with the first part of the small intestine [duodenum], the point of continuity being marked by a thickened ring, which indicates the position of the pyloric sphincter. The duodenum passes towards the under surface of the liver, and then, curving downwards, is lost to sight. If, however, the greater omentum and transverse colon be thrown upwards over the chest, the inferior part of the duodenum can be traced across the vertebral column towards the left side, where it becomes continuous with the coils of the jejunum and ileum. These measure about six metres in length, and if followed downwards the ileum is seen to end in the right iliac fossa by opening into the cæcum, which is the commencement of the large intestine. From the cæcum the large intestine takes an arched course, passing at first upwards on the right side, then across the median plane, and then downwards on the left side, forming respectively the ascending, transverse, and descending parts of the colon. In the pelvis it assumes the form of a loop, termed the pelvic colon, and ends in the rectum.

The spleen lies behind the stomach in the left hypochondriac region, and may be exposed in part by pulling the stomach over towards the right side.

The glistening appearance of the deep surface of the abdominal wall and of the surfaces of the exposed viscera is due to the fact that the former is lined, and the latter are more or less completely covered, with a serous membrane, termed the *peritoneum*.

The Peritoneum

The **peritoneum** is the largest serous membrane in the body, and consists, in the male, of a closed sac, a part of which lines the abdominal parietes, while the remainder is reflected over the contained viscera. In the female the free ends of the uterine tubes open into the peritoneal cavity. The portion which lines the parietes is named the *parietal* portion of the peritoneum; that which is reflected over the contained viscera constitutes the *visceral* portion of the peritoneum. The *free surface* of the membrane is smooth, covered with a layer of flattened endothelium, and lubricated by a small quantity of serous fluid. Hence the viscera can glide on the wall of the cavity or on one another with the least possible amount of friction. The *attached surface* is rough, being connected to the viscera and inner surface of the parietes by means of areolar tissue, termed the *extraperitoneal tissue*. The parietal portion is loosely connected with the fascial lining of the abdomen and pelvis, but is more closely adherent to the under surface of the Diaphragm and to the linea alba.

The parietal and visceral layers of the peritoneum are in actual contact, but the potential space between them is named the *peritoneal cavity*. The peritoneal cavity consists of (1) a main portion, termed the *greater sac*, and (2) a large diverticulum, termed the *lesser sac* (omental bursa), which is situated behind the stomach and adjoining structures; the neck or communication

between the greater sac and the lesser sac is termed the *aditus of the lesser sac* (epiploic foramen).

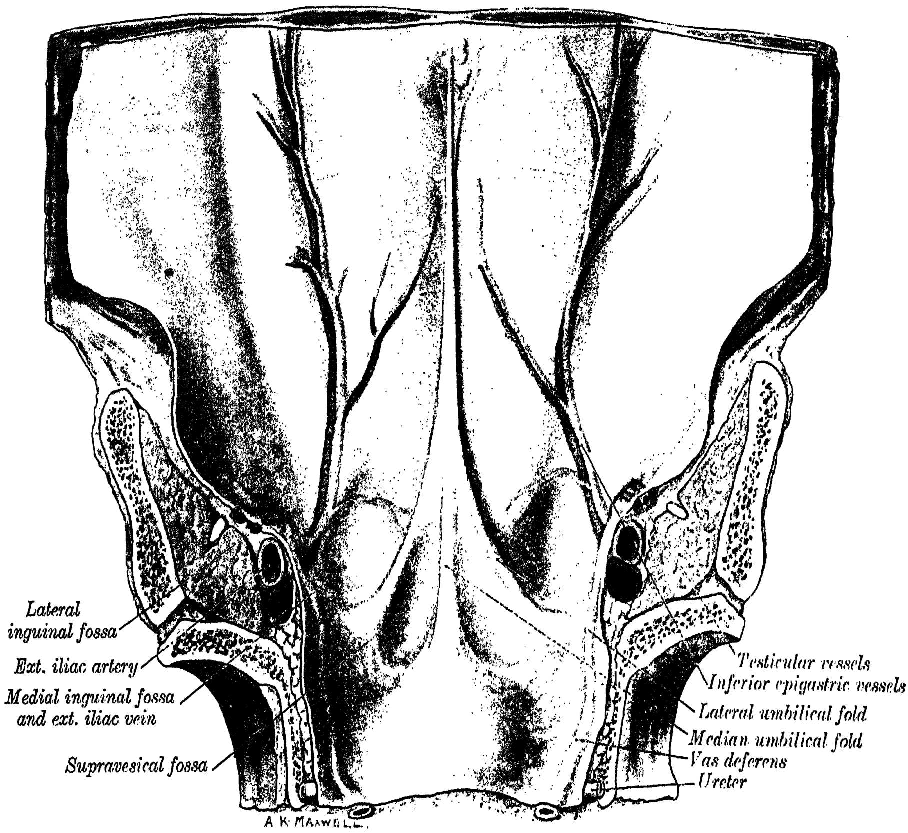
The peritoneum differs from the other serous membranes of the body in presenting a much more complex arrangement, and one that can only be clearly understood by following the development of the digestive tube (pp. 168-177).

To trace the membrane from one viscus to another, and from the viscera to the parietes, it is necessary to follow its continuity in the vertical and horizontal directions, and it is simpler to describe the greater sac and the lesser sac separately.

Vertical disposition of the greater sac (fig. 1160).—It is convenient to trace this from the back of the anterior abdominal wall at the level of the umbilicus. On following the peritoneum upwards from this level it is seen to be reflected around a fibrous cord, termed the *ligamentum teres*, or *obliterated umbilical vein*, which reaches from the umbilicus to the under surface of the liver. This reflection forms a somewhat triangular fold, which is known as the *falciform ligament of the liver*, and attaches the upper and anterior surfaces of the liver to the Diaphragm and abdominal wall. With the exception of the line of attachment of this ligament the peritoneum covers the whole of the under surface of the anterior part of the Diaphragm, and is reflected from it on to the upper surface of the right lobe of the liver as the *superior layer of the coronary ligament*, and on to the upper surface of the left lobe as the *superior layer of the left triangular ligament* of the liver. From the upper and anterior surfaces of the liver, it is continued round the sharp margin of the liver to the under surface, where it has the following relations : (*a*) *To the right of the gall-bladder.* It covers the inferior surface of the right lobe and is reflected from the posterior part of this lobe to the right suprarenal gland and the upper end of the right kidney, forming the *inferior layer of the coronary ligament* ; a special fold, termed the *hepatorenal ligament*, is frequently present between the inferior surface of the liver and the front of the right kidney. From the right kidney it is carried downwards to the duodenum and right colic flexure (fig. 1161), and medially in front of a short segment of the inferior vena cava, where it is continuous with the posterior wall of the lesser sac (fig. 1161). Between the two layers of the coronary ligament there is a large, triangular, surface on the back of the liver devoid of peritoneal covering : this is sometimes named the *bare area* of the liver, and is attached to the Diaphragm by areolar tissue. Towards the right margin of the liver the two layers of the coronary ligament gradually approach each other, and ultimately fuse to form a small triangular fold connecting the right lobe of the liver to the Diaphragm, and named the *right triangular ligament* of the liver (fig. 1202). The apex of the bare area corresponds with the point of meeting of the two layers of the coronary ligament, its base with the groove for the inferior vena cava. (*b*) *To the left of the gall-bladder.* It covers the lower surface of the quadrate lobe of the liver, the under and lateral surfaces of the gall-bladder, and the under surface and posterior border of the left lobe of the liver ; it is then reflected from the upper surface of the left lobe to the Diaphragm as the *inferior layer of the left triangular ligament.* The line of reflection next passes down in the deepest part of the fissure for the ligamentum venosum (figs. 1160 and 1203), and curves to the right along the anterior margin of the porta hepatis. At the right extremity of the latter it becomes continuous with the peritoneum of the lesser sac and will be considered later. From this ⅃-shaped line the peritoneum passes to the lesser curvature of the stomach and the first 2 cm., or less, of the duodenum as the anterior layer of the *hepatogastric* and *hepatoduodenal ligaments*, which together constitute the *lesser omentum.* If this layer of the lesser omentum be followed to the right it will be found to turn round the hepatic artery, bile-duct, and portal vein, and become continuous with the anterior wall of the lesser sac, forming a free folded edge of peritoneum. Traced downwards, the anterior layer of the lesser omentum covers the anterosuperior surface of the stomach and the commencement of the duodenum, and is carried down beyond them into a large free fold, known as the *greater omentum.* Reaching the lower free margin of this fold, it is reflected upwards to cover the under and posterior surfaces of the transverse colon, and thence to the posterior abdominal wall as the inferior

layer of the *transverse mesocolon*. It reaches the abdominal wall at the head and anterior border of the pancreas (fig. 1160), is then carried down over the lower part of the head and over the inferior surface of the pancreas on the superior mesenteric vessels, and thence to the small intestine as the anterior layer of the *mesentery*. It encircles the intestine, and subsequently may be traced, as the posterior layer of the mesentery, upwards and backwards to the abdominal wall. From this it sweeps down over the aorta into the pelvis, where it invests the pelvic colon, and attaches it to the pelvic wall by a fold named the *pelvic mesocolon*. Leaving first the sides and then the front of the rectum, it is reflected

FIG. 1157.—The lower part of the anterior abdominal wall of a male subject. Posterior surface. The peritoneum is in place.



on to the upper ends of the seminal vesicles and the fundus of the urinary bladder, and after covering the upper surface of that viscus, is carried along the median and lateral umbilical ligaments (fig. 1157) on to the back of the abdominal wall to the level from which a start was made.

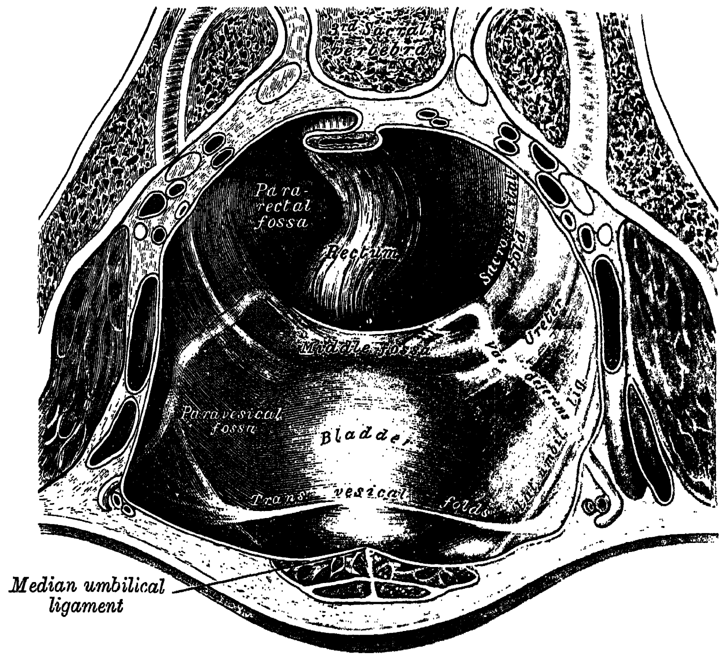
Between the rectum and the bladder it forms, in the male, a pouch, termed the *rectovesical pouch*, the bottom of which is slightly below the level of the upper ends of the seminal vesicles, and about 7·5 cm. from the orifice of the anus. When the bladder is distended, the peritoneum is carried up with it so that a considerable part of the anterior surface of the bladder lies directly against the abdominal wall without the intervention of peritoneal membrane (p. 1372). In the female, the peritoneum is reflected from the rectum over the posterior vaginal fornix to the cervix and body of the uterus, forming the *recto-uterine pouch*. It is continued over the intestinal surface and fundus of the uterus on to its vesical surface, which it covers as far as the junction of the body and neck of the uterus, and then to the bladder, forming here a second, but shallower, pouch, termed the *utero-vesical pouch*. It is also reflected from the side of the uterus to the lateral wall of the pelvis, on each side, as an expanded fold, termed

the *broad ligament of the uterus*, which contains the uterine tube in its free margin.

Horizontal disposition of the greater sac.—Below the transverse colon the arrangement is simple, and it may be considered in the two regions, viz. in the pelvis and in the abdomen proper.

(1) *In the pelvis.*—The peritoneum here follows closely the surfaces of the pelvic viscera and the inequalities of the pelvic walls, and presents important differences in the two sexes. (*a*) *In the male* (fig. 1158) it encircles the pelvic colon, from which it is reflected to the posterior wall of the pelvis as a fold, termed the *pelvic mesocolon*. It leaves the sides and, finally, the front of the rectum, and is continued over the upper parts of the seminal vesicles to the upper surface of the bladder ; on each side of the rectum it forms a *pararectal*

Fig. 1158.—The peritoneum of the male pelvis. (Dixon and Birmingham.)



fossa, which varies in size with the distension of the rectum. In front of the rectum the peritoneum forms the rectovesical pouch, which is limited laterally by peritoneal folds extending from the sides of the bladder to the rectum and sacrum. These folds are known, from their position, as the *sacrogenital folds*. The peritoneum of the anterior pelvic wall covers the superior surface of the bladder, and on each side of this viscus forms a depression, termed the *paravesical fossa*, which is limited laterally by the fold of peritoneum covering the vas deferens. The size of this fossa is dependent on the state of distension of the bladder, and when the bladder is empty, a variable fold of peritoneum, termed the *plica vesicalis transversa*, divides the fossa into two portions. On the peritoneum between the paravesical and pararectal fossæ the only elevations are those produced by the ureters and the internal iliac (hypogastric) vessels. (*b*) *In the female*, pararectal and paravesical fossæ similar to those in the male are present ; the lateral limit of the paravesical fossa is the peritoneum investing the round ligament of the uterus. The rectovesical pouch is, however, divided by the uterus and vagina into a small, anterior utero-vesical and a deep, posterior, recto-uterine pouch (fig. 1245). The sacrogenital folds form the margins of the latter, and are continued on to the back of the uterus and the posterior fornix of the vagina as a transverse fold. The *broad ligaments* extend from the sides of the uterus to the lateral walls of the pelvis ; the uterine tubes are contained in their free margins, and the ovaries are attached to their

posterior layers. Below, the broad ligaments are continuous with the peritoneum on the lateral walls of the pelvis. In the angle between the elevations produced by the obliterated umbilical artery and the ureter on the lateral pelvic wall, there is a shallow fossa, known as the *ovarian fossa,* in which the ovary lies in the nulliparous female. It is situated behind the lateral attachment of the broad ligament.

(2) *In the lower abdomen.*—The peritoneum lining the lower part of the anterior abdominal wall is raised into five ridges or folds which converge as they pass upwards. One of these is placed in the median plane and extends from the apex of the urinary bladder to the umbilicus. It contains the urachus (p. 194) and is termed the *median umbilical fold.* To the lateral side the obliterated umbilical artery forms the *lateral umbilical fold,* as it ascends from the pelvis towards the umbilicus. The depression between the two umbilical folds is termed the *supravesical fossa.* Further to the lateral side, the inferior epigastric artery raises a fold below the point at which it enters the sheath of the Rectus muscle. The *medial inguinal fossa* is the depression situated between the epigastric and the lateral umbilical folds ; the *lateral inguinal fossa,* which overlies the deep inguinal ring, lies to the lateral side of the epigastric fold. A fourth depression is placed below and slightly medial to the lateral inguinal fossa and is separated from it by the medial end of the inguinal ligament. It overlies the femoral ring (p. 785) and is termed the *femoral fossa.*

Traced from the linea alba, below the level of the transverse colon, and followed in a horizontal direction to the right, the peritoneum covers the inner surface of the abdominal wall almost as far as the lateral border of the Quadratus lumborum ; it encloses the cæcum and vermiform appendix, and is reflected over the sides and front of the ascending colon ; it may then be traced over the duodenum, Psoas major, and inferior vena cava towards the median plane, whence it passes along the mesenteric vessels to invest the small intestine, and back again to the large vessels in front of the vertebral column, forming the *mesentery* (figs. 1160 and 1161), the layers of which enclose the jejunum, ileum, the mesenteric blood-vessels, nerves, lacteals and lymph glands. It is then continued over the left Psoas major ; it covers the sides and front of the descending colon, and, reaching the abdominal wall, is carried on it to the median plane.

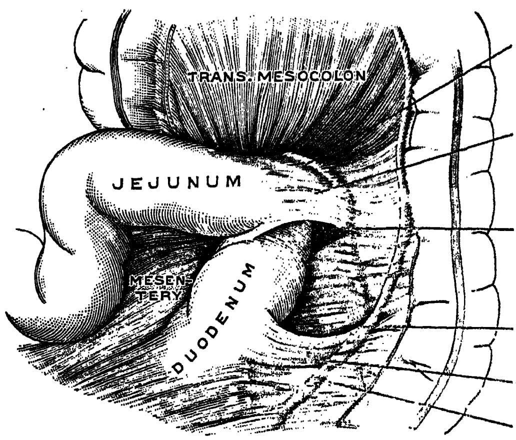
(3) *In the upper abdomen* (fig. 1162).—Above the transverse colon, the peritoneum on the posterior abdominal wall at the inferior vena cava may be followed to the right over the front of the right suprarenal gland and upper part of the right kidney to the anterolateral abdominal wall. From the anterior median line a double fold passes backwards and to the right, to become continuous with the peritoneum investing the liver, and forms the falciform ligament. Continuing to the left, the peritoneum lines the anterolateral abdominal wall and covers the lateral part of the front of the left kidney, and is reflected to the posterior border of the hilum of the spleen as the posterior or lateral layer of the *lienorenal ligament* (fig. 1162). It can be traced over the surfaces of the spleen to the front of the hilum, and thence to the cardiac end of the greater curvature of the stomach as the left layer of the *gastrosplenic ligament.* It covers the anterosuperior surface of the stomach and commencement of the duodenum, and ascends from the lesser curvature of the stomach to the liver as the anterior layer of the lesser omentum.

The lesser sac of peritoneum (omental bursa).—The *lesser sac* is a large recess of irregular outline which lies behind the stomach and extends beyond its limits. Its anterior and posterior walls are extensive and they are limited by variable lower, right, left and upper borders. The recess is completely shut off from the greater sac except in the upper part of its right border where a free communication is established through a slit-like opening. In its upper part the posterior wall of the lesser sac is formed by a single layer of peritoneum, closely applied to the posterior abdominal wall (fig. 1160), but below the pancreas, the sac is carried into the interior of the greater omentum and its posterior wall is formed by the posterior two layers of that structure and the transverse mesocolon (fig. 1160).

The *aditus to the lesser sac* (epiploic foramen) is a short, slit-like passage which leads out from the upper part of the right border of the lesser sac into

the greater sac. Its *anterior wall* is formed by the right margin of the lesser omentum, which contains between its two layers in this situation the bile-duct, the portal vein and the hepatic artery (fig. 1162). Traced upwards, the two layers separate and the posterior layer covers the caudate process, forming the *roof* of the aditus (fig. 1164), and then descends in front of the inferior vena cava, forming the *posterior wall* of the aditus. At, or a little below, the upper border of the first part of the duodenum, this layer passes forwards to become continuous with the posterior layer of the lesser omentum, and in this situation, it forms the *floor* of the aditus. The medial end of the floor * is continuous with the right border of the lower part of the sac (fig. 1161), and it is by passing forwards below the medial end of the floor that the hepatic artery is able to insinuate itself between the two layers of the lesser omentum. Traced laterally, i.e. to the right, all the boundaries of the aditus to the lesser sac become continuous with peritoneum of the greater sac. The roof is continuous with the peritoneal covering of the inferior surface of the right lobe of the liver (fig. 1203); the posterior wall with the peritoneum on the right suprarenal gland (fig. 1161); the anterior wall with the anterior layer of the lesser omentum round the bile-

Fig. 1159.—The superior and inferior duodenal recess. (After Jonnesco.) From Poirier and Charpy's *Traité d'Anatomie humaine*. (Masson et Cie.)



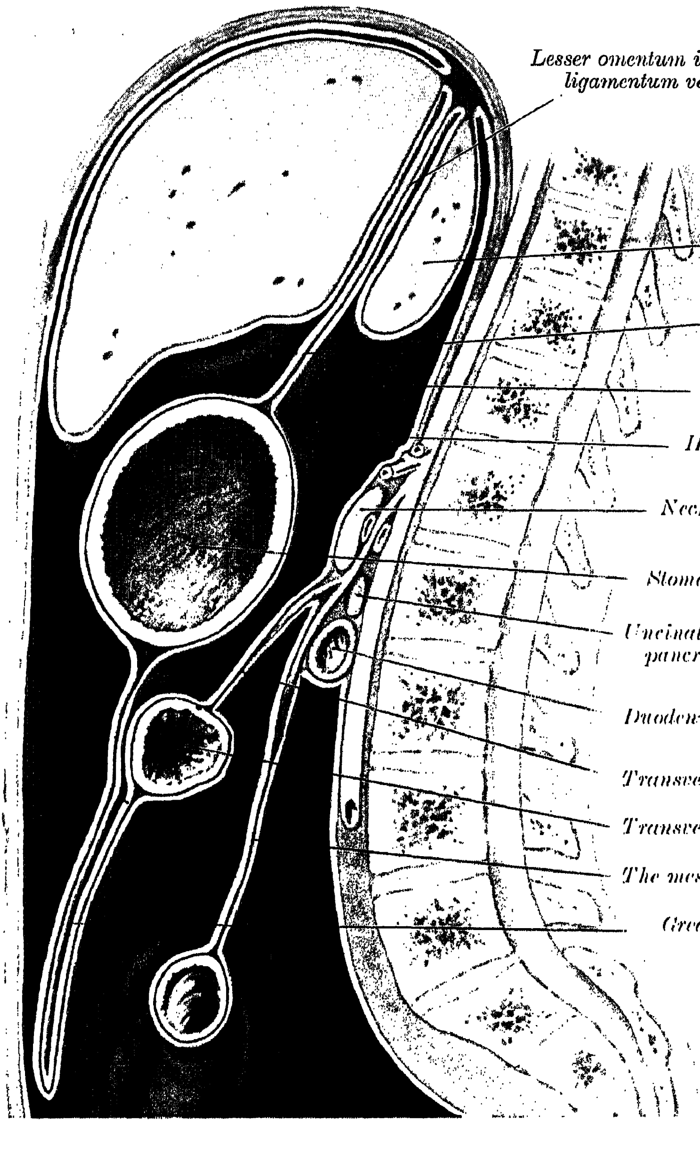
duct (fig. 1162); the floor with the peritoneum covering the lower part of the right suprarenal gland and the adjacent parts of the duodenum and right kidney.

The *lesser sac of peritoneum* (omental bursa) and its boundaries can now be considered in detail. The *anterior wall* is formed (1) by the peritoneum which covers the postero-inferior aspect of the stomach and the first 2 cm., or less, of the duodenum. Traced downwards this layer becomes the posterior of the anterior two layers of (2) the greater omentum; traced upwards and to the right, it leaves the stomach along the lesser curvature and the duodenum at its upper border, and becomes the posterior layer of (3) the lesser omentum. The lesser sac is usually described as passing upwards *behind* the caudate lobe of the liver, but this description is scarcely accurate, for the caudate lobe projects into the bursa from its right border and is covered by peritoneum on its anterior as well as on its posterior surface (fig. 1160).

The *posterior wall* is formed by the anterior of the posterior two layers of the greater omentum (when its constituent layers are not fused with one another), the peritoneum on the anterior aspect of the transverse colon, and the upper layer of the transverse mesocolon (fig. 1160). Above the inferior border of the pancreas, the posterior wall of the omental bursa lines the posterior abdominal wall, covering a small part of the front of the head, and the whole of the front of the neck and body of the pancreas, a small part of the anterior aspect of the left kidney and most of the anterior aspect of the left suprarenal gland, the

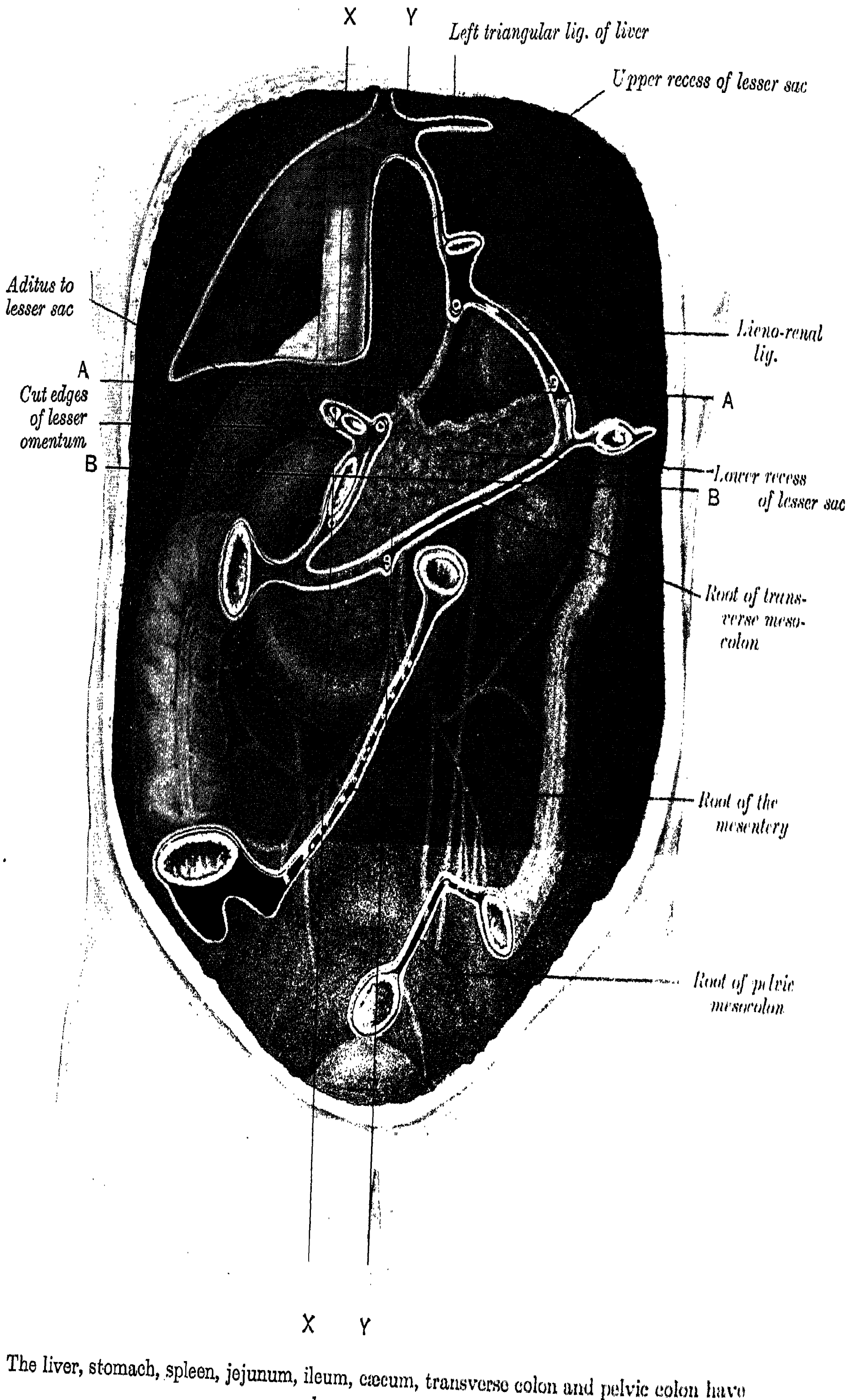
* In the B.N.A. the medial part of the aditus to the lesser sac is termed the *vestibule* of the omental bursa.

FIG. 1160.—A sagittal section through the abdomen, approximately in the median plane. Diagrammatic.



The section cuts the posterior abdominal wall along the line YY in Fig. 1161. The peritoneum is shown in *blue* except along cut edges, which are left *white*.

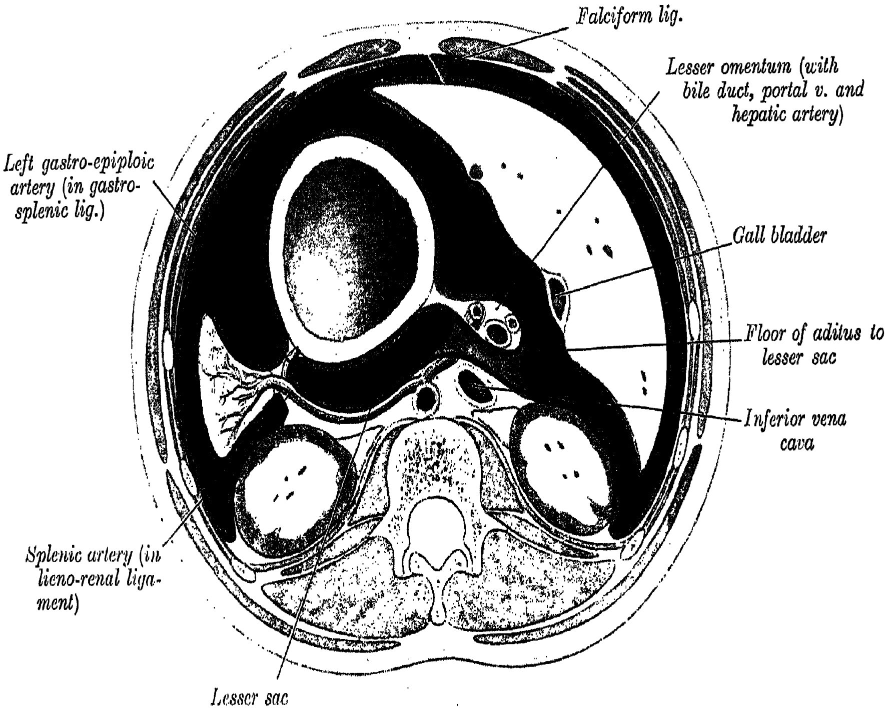
Fig. 1161.—The posterior abdominal wall, showing the lines of peritoneal reflexion.



The liver, stomach, spleen, jejunum, ileum, cæcum, transverse colon and pelvic colon have been removed.

Line YY represents the plane of Fig. 1160.
Line XX represents the plane of Fig. 1164.
Line AA represents the plane of Fig. 1162.
Line BB represents the plane of Fig. 1163.

Fig. 1162.—A transverse section through the abdomen, at the level of line AA, Fig. 1161, viewed from above. Diagrammatic.



The peritoneal cavity is shown in *dark blue*; the peritoneum and its cut edges in *lighter blue*.

Fig. 1163.—A transverse section through the abdomen, at the level of line BB in Fig. 1161, viewed from above. Diagrammatic. Colours as above.

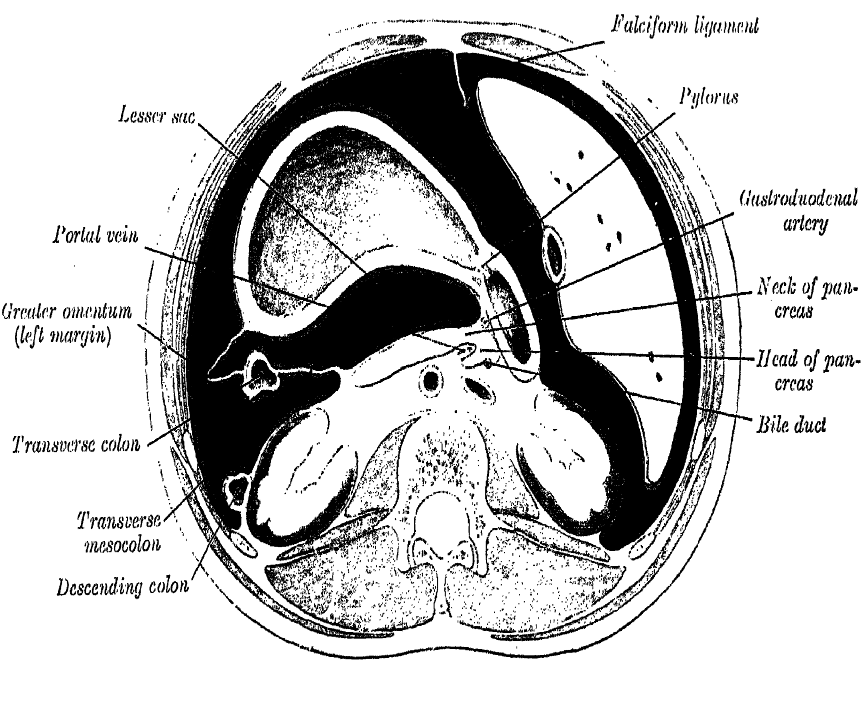
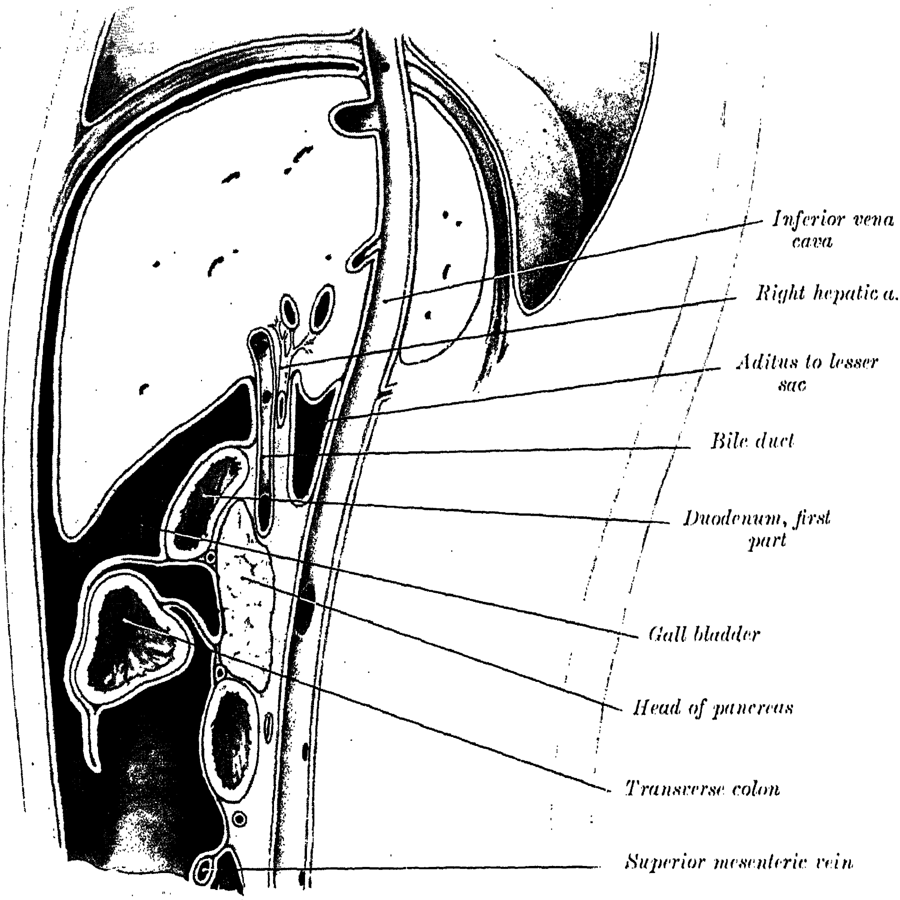


FIG. 1164.—A sagittal section through the upper part of the abdominal cavity, along the line XX in Fig. 1161.



The boundaries of the aditus to the lesser sac are shown, and a small recess of the lesser sac is displayed in front of the head of the pancreas.

commencement of the abdominal aorta and the coeliac artery, and a considerable area of the Diaphragm. In addition, the (inferior) phrenic, the splenic, the left gastric and, to a much smaller extent, the hepatic arteries course behind the lesser sac (figs. 1161 and 1162).

The borders of the lesser sac of peritoneum are formed by the lines along which the peritoneal posterior wall is reflected to become continuous with the peritoneal anterior wall, and they are subject to considerable variation. The *lower border* is, developmentally (p. 177), the lower border of the greater omentum, but partial fusion of the constituent layers of this fold makes the border very irregular in the adult, and, as a rule, it does not extend much below the transverse colon. The *upper border* of the lesser sac is narrow and extends between the right side of the œsophagus and the upper end of the fissure for the ligamentum venosum of the liver. In this interval the peritoneal posterior wall of the sac is reflected forwards from the Diaphragm and becomes continuous with the posterior layer of the lesser omentum.

The *right border* of the lesser sac corresponds below to the right free border of the greater omentum. Above the upper end of the latter it is formed by the reflexion of the peritoneum from the neck and head of the pancreas on to the posterior surface of the duodenum (fig. 1163). The line of this reflexion passes upwards and to the left along the medial side of the gastroduodenal artery. Near the upper border of the duodenum the right border becomes continuous with the floor of the aditus to the lesser sac round the hepatic artery (fig. 1161). Above the opening, which interrupts its continuity, the right border is formed by the reflexion of the peritoneum from the Diaphragm to the right margin of the caudate lobe of the liver and it follows the left edge of the inferior vena cava (fig. 1161).

The *left border* of the lesser sac is formed, below, by the left free margin of the greater omentum. Above the root of the transverse mesocolon (fig. 1161) the left border is broader. It is formed by the *lienorenal* and the *gastrosplenic ligaments*, which together represent a part of the original dorsal mesogastrium (p. 168). The lienorenal ligament extends from the front of the left kidney to the hilum of the spleen as a two-layered fold, in which the splenic vessels and the tail of the pancreas (figs. 1161 and 1162) are enclosed. From the hilum of the spleen these two layers are continued forwards to the greater curvature of the stomach as the gastrosplenic ligament. There is no breach in the continuity of the inner layer (fig. 1162), but the continuity of the outer layer is interrupted by the spleen, which projects it into the greater sac. At their upper ends the lienorenal and the gastrosplenic ligaments merge into a short fold, termed the *gastrophrenic ligament*, which passes from the Diaphragm, behind, to the posterior aspect of the fundus of the stomach, in front. The two layers of this ligament diverge as they approach the œsophagus and a part of the posterior surface of the stomach is left devoid of peritoneal covering (fig. 1161). In this situation the upper end of the left border becomes continuous with the left extremity of the roof and the left gastric artery turns forwards to gain the lesser omentum.

The interior of the lesser sac is encroached on by two, more or less sickle-shaped, folds of peritoneum which are drawn into the sac by the hepatic and left gastric arteries. The upper or *left gastropancreatic fold* is formed by the left gastric artery as it passes from the posterior abdominal wall to reach the lesser curvature of the stomach ; the lower or *right gastropancreatic fold* is formed by the hepatic artery as it passes forwards from the posterior abdominal wall to gain the lesser omentum. The folds show considerable variation in their depths but, when well marked, they constrict the lesser sac and enclose a foramen which is sometimes called the *foramen bursæ omenti majoris*. The *superior recess* of the lesser sac lies above the foramen and communicates through it with the *inferior recess*, which represents the true *bursa omenti majoris* of the embryo (p. 174).

During a considerable part of fœtal life the transverse colon is suspended from the posterior abdominal wall by a mesentery of its own, the posterior two layers of the greater omentum passing at this stage in front of the colon (fig. 215). This condition occasionally persists throughout life, but as a rule adhesion occurs between the mesentery of the transverse colon and the posterior layer of the greater omentum, with the result that the colon appears to receive its

peritoneal covering by the splitting of the posterior two layers of the latter fold. In the adult the lesser sac intervenes between the stomach and the structures on which that viscus lies, and performs therefore the functions of a serous bursa for the stomach.

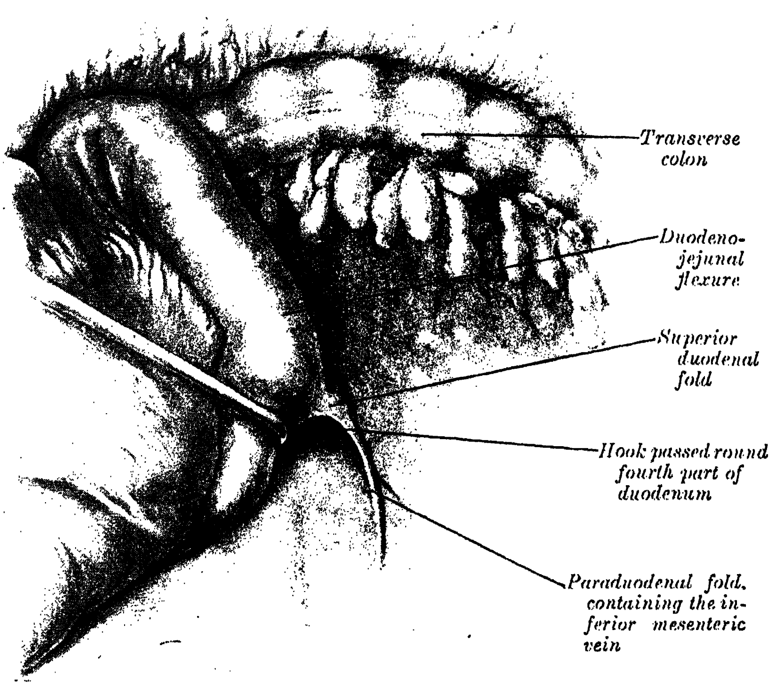
Numerous peritoneal folds extend between the various organs or connect them to the parietes; they serve to enclose the vessels and nerves proceeding to the viscera and, although they are clearly not designed to sustain any weight, they help to retain certain of the viscera in contact with one another. They are grouped as ligaments, omenta and mesenteries.

The **ligaments** will be described with their respective organs.

There are two **omenta**, the lesser and the greater.

The *lesser omentum* is the fold of peritoneum which extends to the liver from the lesser curvature of the stomach and the commencement of the duodenum. It is continuous with the two layers which cover the antero-superior

Fig. 1165.—The superior duodenal recess.

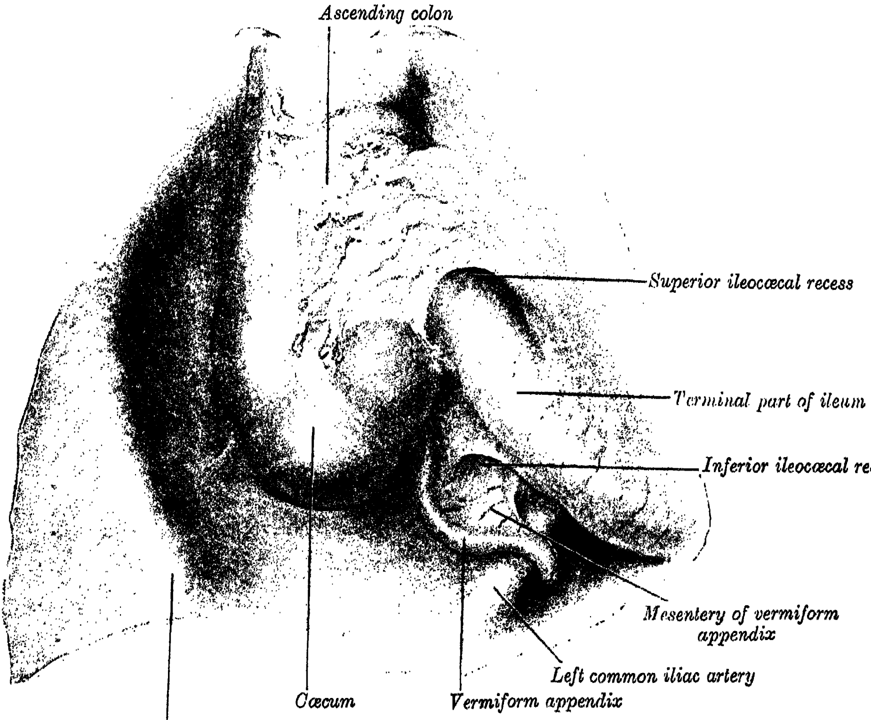


and postero-inferior surfaces of the stomach and the first 2 cm., or less, of the duodenum. From the lower part of the lesser curvature of the stomach and the upper border of the duodenum, these two layers ascend as a double fold to the porta hepatis; from the upper part of the lesser curvature, the two layers pass to be attached to the bottom of the fissure for the ligamentum venosum. The hepatic attachment of the lesser omentum is, therefore, ⅃-shaped, the horizontal limb corresponding to the margins of the porta hepatis, and the vertical limb to the floor of the fissure for the ligamentum venosum. At the upper end of the latter, the lesser omentum reaches the Diaphragm, where the two layers separate to embrace the end of the œsophagus. At the right border of the omentum the two layers are continuous, and form a free margin which constitutes the anterior boundary of the aditus to the lesser sac (epiploic foramen). The portion of the lesser omentum extending between the liver and stomach is sometimes named the *hepatogastric ligament*, and that between the liver and duodenum the *hepatoduodenal ligament*. Close to its right free margin the two layers of the lesser omentum enclose the hepatic artery, portal vein and bile duct, a few lymph glands and lymph vessels, and the hepatic plexus of nerves—all these structures being enclosed in a fibrous capsule, termed the *hepatobiliary capsule*

(Glisson's capsule). The right and left gastric arteries, the corresponding veins and some of the superior gastric lymph glands and their vessels, run between the layers of the lesser omentum, where these are attached to the stomach.

The *greater omentum* is the largest peritoneal fold. It consists of a double sheet, folded on itself so that it is made up of four layers. The two layers which descend from the stomach and commencement of the duodenum pass downwards in front of the small intestine for a variable distance; they then turn upon themselves, and ascend again as far as the transverse colon, where they separate and enclose that part of the intestine. These individual layers may be demonstrated in the young subject, but in the adult they are more or less inseparably blended. The left border of the greater omentum is continuous above with the gastrosplenic ligament; its right border extends as far as the

FIG. 1166.—The terminal part of the ileum, the cæcum and the vermiform appendix. Viewed from in front.



commencement of the duodenum. The greater omentum is usually thin, and presents a cribriform appearance, but it always contains some adipose tissue, which in fat people is present in considerable quantity. Between its anterior two layers, about a finger's breadth from the greater curvature of the stomach, the right and left gastro-epiploic vessels anastomose with each other.

The mesenteries are :—the mesentery (mesentery proper), the mesentery of the vermiform appendix, the transverse mesocolon and the pelvic mesocolon. In addition to these an ascending and a descending mesocolon are sometimes present.

The *mesentery* is a broad, fan-shaped fold of peritoneum connecting the coils of the jejunum and ileum with the posterior wall of the abdomen. Its root —the border connected with the posterior abdominal wall—is about 15 cm. long, and is directed obliquely from the duodeno-jejunal flexure at the left side of the second lumbar vertebra to the right sacroiliac joint (fig. 1161). Its intestinal border is about 6 metres long; and here the two layers separate to enclose the intestine and form its peritoneal coat. The mesentery is short at the upper part of the jejunum, but lengthens rapidly to about 20 cm. and is thrown into

numerous pleats or folds. It connects the jejunum and ileum to the posterior abdominal wall, and contains between its layers the jejunal and ileal branches of the superior mesenteric artery, with their accompanying veins and plexuses of nerves, the lymph vessels (lacteals), the mesenteric lymph glands and a varying amount of fatty tissue. At the upper end of the mesentery the fat tends to accumulate near its root, but as the fold is traced downwards, the fat extends farther towards the gut until, at the lower end of the ileum, it may entirely obscure the mesenteric border of the gut.

The *mesentery of the vermiform appendix* (fig. 1166) is a triangular fold of peritoneum which clothes the vermiform appendix, and is attached to the back of the lower end of the mesentery, close to the ileocæcal junction. Its layers enclose the blood-vessels, nerves and lymph vessels of the vermiform appendix, together with a lymph gland.

The *transverse mesocolon* is a broad fold connecting the transverse colon to the posterior wall of the abdomen. It is continuous with the posterior two layers of the greater omentum, which, after separating to surround the transverse colon, join behind it and are continued to the anterior border of the pancreas, where they separate (figs. 1160 and 1161). Between the layers of the transverse mesocolon the blood-vessels, nerves and lymphatics of the transverse colon are found. The middle colic artery passes downwards and to the right, leaving a large non-vascular area of the fold to its left, and a similar but smaller area to its right.

The *pelvic mesocolon* is a fold of peritoneum which attaches the pelvic colon to the pelvic wall. Its line of attachment has the form of an inverted V, the apex of which is near the point of division of the left common iliac artery (fig. 1161); the left limb descends on the medial side of the Psoas major; the right limb passes into the pelvis and ends in the median plane at the level of the third sacral vertebra. The inferior left colic (sigmoid) and superior rectal (superior hæmorrhoidal) vessels run between the two layers of the pelvic mesocolon.

In most cases the peritoneum covers only the front and sides of the ascending and descending parts of the colon, but sometimes these are surrounded by peritoneum and attached to the posterior abdominal wall by an ascending and a descending mesocolon respectively (p. 1336*). A fold of peritoneum, termed the *phrenicocolic ligament*, is continued from the left colic flexure to the Diaphragm opposite the tenth and eleventh ribs; it passes below and lateral to the lateral end of the spleen, and is sometimes given the misleading name of *sustentaculum lienis*.

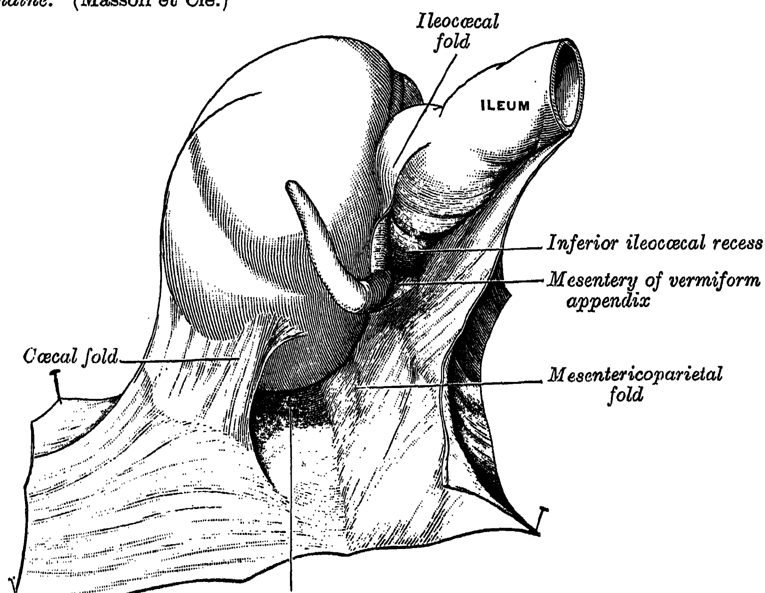
The *appendices epiploicæ* are small pouches of the peritoneum filled with fat and situated along the colon; they are best marked on the transverse and pelvic parts of the colon.

Peritoneal recesses.—In certain parts of the abdominal cavity there are peritoneal recesses or pouches, which are of surgical interest in connexion with the possibility of the occurrence of 'internal' herniæ. The largest of these is the lesser sac (p. 1309), but others of smaller size require mention, and may be divided into three groups, viz.: duodenal, cæcal, and the recess of the pelvic mesocolon.

1. *Duodenal recesses* (figs. 1159 and 1165).—Five of these recesses are usually described, viz. a superior and an inferior duodenal, a paraduodenal, a retroduodenal and a duodenojejunal or mesocolic. The paraduodenal recess may occur together with the superior and inferior duodenal recesses, but the retroduodenal and duodenojejunal are not found in conjunction with the other varieties. (*a*) The *superior duodenal recess* (fig. 1165) is present in about 50 per cent. of bodies. It lies on the left side of the upper segment of the fourth part of the duodenum, behind a sickle-shaped fold of peritoneum, named the superior duodenal fold; the upper part of the inferior mesenteric vein usually runs between the layers of this fold. The fossa is about 2 cm. deep, and its orifice, directed downwards, admits a finger-tip. (*b*) The *inferior duodenal recess* (fig. 1159) is present in about 75 per cent. of bodies. It is placed on the left side of the lower segment of the fourth part of the duodenum behind a nonvascular triangular fold of peritoneum, named the inferior duodenal fold. This fossa has an average depth of 3 cm., and its orifice, which admits the tips of one or two

fingers, is directed upwards and faces that of the superior duodenal recess. In some cases the recess extends to the left in front of the ascending branch of the superior left colic artery, and the inferior mesenteric vein. (*c*) The *paraduodenal recess* (fig. 1165) lies a short distance to the left of the fourth part of the duodenum, and, though frequently present in the new-born child, is rarely found in the adult. It is placed behind a falciform fold [paraduodenal fold] of peritoneum, the free edge of which contains the ascending branch of the superior left colic artery, and frequently the inferior mesenteric vein, the fold forming a mesentery for these vessels. The free margin of the fold, and the wide orifice of the recess, are directed towards the right. (*d*) The *retroduodenal recess*, the largest of the duodenal recesses, is only occasionally present. It lies behind the third and fourth parts of the duodenum, and in front of the aorta, and extends upwards nearly as far as the duodenojejunal junction. The orifice of the recess looks

FIG. 1167.—The cæcal recesses. The ileum and cæcum are drawn backwards and upwards. (After Jonnesco.) From Poirier and Charpy's *Traité d'Anatomie humaine*. (Masson et Cie.)



downwards and to the left. (*e*) The *duodenojejunal* or *mesocolic recess* lies on the left side of the aorta, between the duodenojejunal junction and the root of the transverse mesocolon. It is present in about 20 per cent. of bodies, and has an average depth of from 2 cm. to 3 cm. Its orifice is directed forwards.

2. *Cæcal recesses.*—There are three principal pouches or recesses in the neighbourhood of the cæcum : (*a*) The *superior ileocæcal recess* (fig. 1166) is formed by a fold of peritoneum, named the vascular fold of the cæcum, arching over the branch of the ileocolic artery which supplies the ileocolic junction. The recess is a narrow chink situated between the mesentery of the small intestine, and the ileum and the small portion of the cæcum behind. Its mouth opens downwards. (*b*) The *inferior ileocæcal* recess (fig. 1166) is situated behind the angle of junction of the ileum and cæcum. It is formed by the *ileocæcal fold* of peritoneum (described by Treves as the ' bloodless fold '), the upper border of which is fixed to the ileum opposite its mesenteric attachment, while the posterior or right border joins the mesentery of the vermiform appendix, and sometimes the appendix itself or the cæcum. Between this fold and the mesentery of the vermiform appendix the inferior ileocæcal recess lies. It is bounded above by the posterior surface of the ileum and the mesentery ; in front by the ileocæcal fold, and behind by the upper part of the mesentery of the vermiform appendix. (*c*) The *cæcal recess* (fig. 1167) is situated immediately behind the cæcum, which has to be raised to bring it into view. It varies much in size and extent. In some cases it is sufficiently large to admit the index finger ; in others it is merely

a shallow depression. It is bounded on the right by the cæcal fold, which extends downwards and to the right into the iliac fossa from the posterolateral aspect of the lower part of the ascending colon, or upper part of the cæcum. The *retrocæcal recess* is an occasional extension of the cæcal recess upwards behind the ascending colon.

3. The *recess of the pelvic mesocolon* (intersigmoid recess) is constant in the fœtus and during infancy, but may disappear as age advances. It lies on the pelvic side of the apex of the root of the pelvic mesocolon (p. 1314) and forms a funnel-shaped recess of variable size, the mouth of which opens downwards. In some instances it is a mere dimple. The posterior wall of the recess covers the left ureter as it crosses the bifurcation of the left common iliac artery.

The Stomach [Ventriculus]

The **stomach** is the most dilated part of the digestive tube, and is situated between the end of the œsophagus and the beginning of the small intestine. It lies in the epigastric, umbilical, and left hypochondriac regions of the abdomen, and occupies a recess bounded by the upper abdominal viscera, and completed in front and on the left side by the anterior abdominal wall and the Diaphragm.

The *shape* and *position* of the stomach are so greatly modified by changes within itself and in the surrounding viscera that no one form and no single position can be described as typical. The chief modifications are determined by (1) the amount of the stomach contents, (2) the stage which the digestive process has reached, (3) the degree of development of the gastric musculature, and (4) the condition of the adjacent intestines ; but certain features are more or less common to all.

The stomach has two openings, two borders or curvatures, and two surfaces.

Openings.—The opening by which the œsophagus communicates with the stomach is known as the *cardiac orifice*, and is situated on the left of the median plane, behind the seventh costal cartilage one inch from its junction with the sternum, and at the level of the eleventh thoracic vertebra. The short abdominal portion of the œsophagus is conical in shape and curved sharply to the left, the base of the cone being continuous with the cardiac orifice of the stomach. The right margin of the œsophagus is continuous with the lesser curvature of the stomach, while the left margin joins the greater curvature at an acute angle, termed the *cardiac notch* [incisura cardiaca].

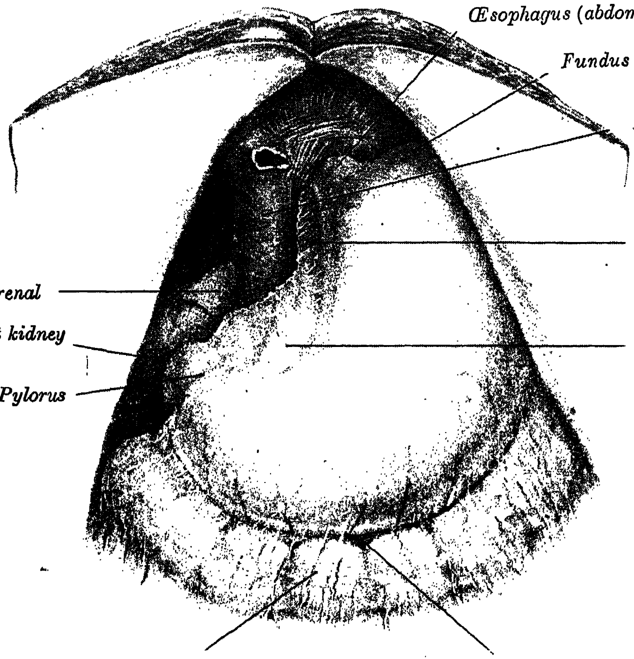
The opening by which the stomach communicates with the duodenum is named the *pyloric orifice*, and its position is usually indicated (fig. 1168) by a circular groove on the surface of the organ, termed the *pyloric constriction*, which indicates the position of the pyloric sphincter. In the living subject, at operation, it can be identified by the prepyloric vein, which runs vertically across its anterior surface. The pyloric orifice lies 1·5 cm. to the right of the median plane at the level of the lower border of the first lumbar vertebra, *when the body is in the supine position.*

Curvatures.—The *lesser curvature*, extending between the cardiac and pyloric orifices, forms the right or posterior border of the stomach. It descends as a continuation of the right margin of the œsophagus in front of the decussating fibres of the right crus of the Diaphragm, and then, turning to the right, it curves below the omental tuberosity of the pancreas and ends at the pylorus (fig. 1168). The deepest part of the curve forms a notch, named the *angular notch* [incisura angularis], which varies somewhat in position with the state of distension of the viscus ; it serves to separate the stomach into a right and a left portion. The lesser curvature gives attachment to the lesser omentum, the two layers of which contain the right and left gastric vessels.

The *greater curvature* is directed mainly forwards, and is four or five times as long as the lesser curvature. Starting from the cardiac orifice at the cardiac notch, it forms an arch backwards, upwards, and to the left ; the highest point of the convexity is on a level with the left fifth intercostal space. From this level it may be followed downwards and forwards, with a slight convexity to the left almost as low as the cartilage of the tenth rib, when the body is in the supine position ; it then turns to the right, to end at the pylorus. Directly opposite

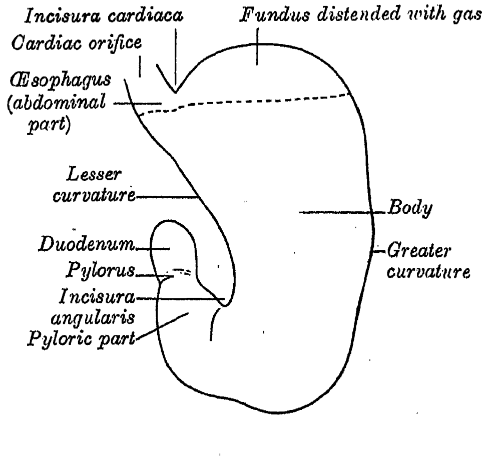
the incisura angularis of the lesser curvature the greater curvature presents a bulging, which is the left extremity of the *pyloric part* of the stomach ; this is limited on the right by a slight groove, which indicates the subdivision of the

Fig. 1168.—The stomach *in situ*, after the removal of the liver.



pyloric part into a pyloric antrum and a pyloric canal. The latter is only 2 to 3 cm. in length and terminates at the pyloric constriction. At its commencement the greater curvature is covered by peritoneum continuous with that on the front of the stomach. On the left side of the fundus and the adjoining part of the body, the greater curvature gives attachment to the gastrosplenic ligament, while its lower portion gives attachment to the two layers of the greater omentum, separated from each other by the gastro-epiploic vessels.

Fig. 1169.—An outline of the normal full stomach. (From a model by A. E. Barclay.)



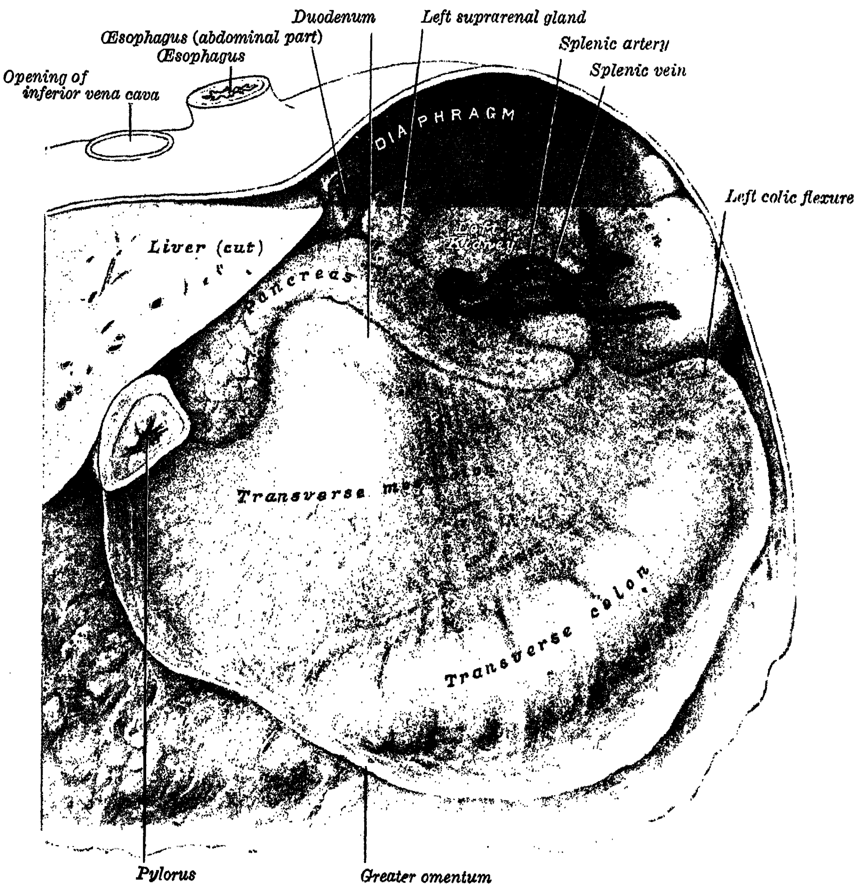
Surfaces.—When the stomach is empty and its walls contracted, its surfaces are directed upwards and downwards respectively, but when it is distended they look forwards and backwards. They may therefore be described as antero-superior and postero-inferior.

Anterosuperior surface. — The left part of this surface lies under cover of the left costal margin. It is in contact with the Diaphragm, which separates it from the left pleura, the base of the left lung, the pericardium, and the sixth, seventh, eighth and ninth ribs and intercostal spaces of the left side. It is also in contact with the upper fibres of origin of the transversus abdominis, which intervene between it and the seventh, eighth and ninth costal cartilages. The right half is in relation with the left and quadrate lobes of the liver and with

the anterior abdominal wall. When the stomach is empty, the transverse colon may lie on the front part of this surface. The whole surface is covered with peritoneum.

The *postero-inferior surface* is in relation with the Diaphragm, the gastric surface of the spleen, the left suprarenal gland, the upper part of the front of the left kidney, the splenic artery, the anterior surface of the pancreas, the left colic flexure, and the upper layer of the transverse mesocolon. These structures form the shallow *stomach-bed*, on which the viscus rests (fig. 1170). The transverse mesocolon separates the stomach from the duodenojejunal

Fig. 1170.—The 'stomach-bed.'



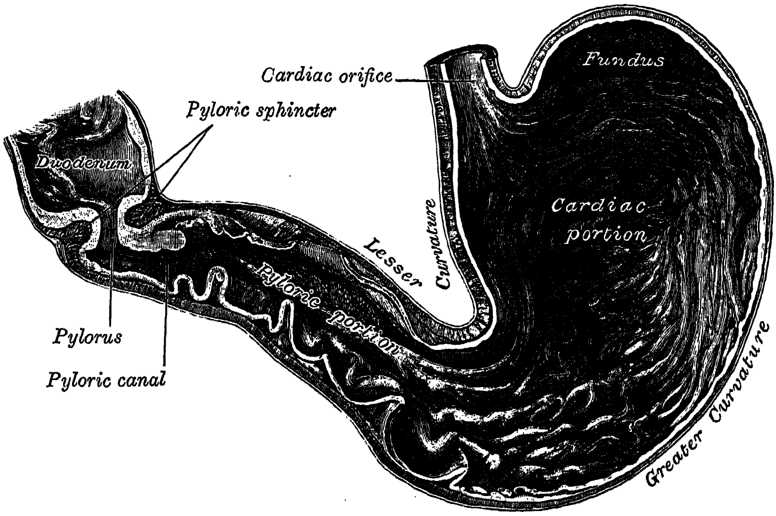
flexure and small intestine. The postero-inferior surface is covered with peritoneum, except near the cardiac orifice, where there is a small, somewhat triangular, area, about 5 cm. wide, in direct contact with the left crus of the Diaphragm, and sometimes with the left suprarenal gland. The left gastric vessels reach the lesser curvature of the stomach at the right extremity of this area, and from its left side a short peritoneal fold, termed the *gastrophrenic ligament*, which is continuous below with the lienorenal and gastrosplenic ligaments, passes to the inferior surface of the Diaphragm.

A plane passing through the incisura angularis on the lesser curvature and the left limit of the opposed bulging on the greater curvature divides the stomach into a large, left portion or *body* and a small, right, or *pyloric portion*. The upper portion of the body is known as the *fundus* and is marked off from the remainder of the body by a plane passing horizontally through the cardiac orifice.

By means of *x*-rays the form and position of the stomach can be studied in the living subject after the administration of a meal containing bismuth (Pl. XV). During the process of digestion, it is divided by a muscular constriction into a large, dilated, left portion, and

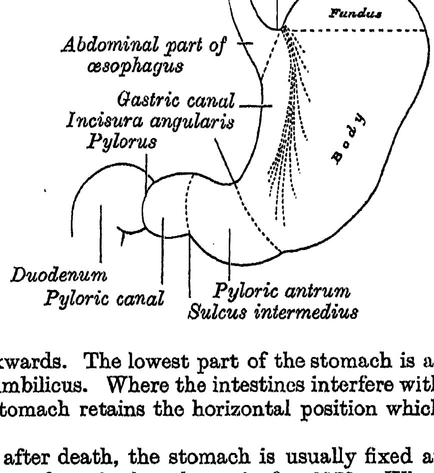
a narrow, contracted, tubular, right portion. The constriction is in the body of the stomach, and does not follow any of the anatomical landmarks; indeed, it shifts gradually towards the left as digestion progresses. The position of the stomach varies with the posture, with the amount of the stomach contents and with the condition of the intestines on which it rests. In addition there is a wide range of individual varia-

FIG. 1171.—The interior of the stomach.



tion. In the erect posture the empty stomach is somewhat J-shaped; the fundus is usually distended with gas; the pylorus descends to the level of the second or the upper part of the third lumbar vertebra, and the most dependent part of the stomach is below the level of the umbilicus. Variation in the amount of its contents affects mainly the body of the stomach, the pyloric portion remaining in a more or less contracted condition during the process of digestion. As the stomach fills it tends to expand forwards and downwards in the direction of least resistance, but when this is interfered with by a distended condition of the colon or intestines the fundus presses upwards on the liver and Diaphragm and gives rise to the feelings of oppression and palpitation complained of in such cases. By hardening the viscera *in situ* His * and Cunningham † have shown that the contracted stomach has a sickle shape, the fundus looking directly backwards. The surfaces are directed upwards and downwards, the upper surface having, however, a gradual downward slope to the right. The greater curvature is in front and at a slightly higher level than the lesser.

FIG. 1172.—A diagram showing the subdivisions of the human stomach. (F. T. Lewis.)



The position of the full stomach depends, as already indicated, on the state of the intestines: when the latter are empty the fundus expands vertically and also forwards, the pylorus is displaced towards the right, and the whole organ assumes an oblique position, so that its surfaces are directed more forwards and backwards. The lowest part of the stomach is at the pyloric antrum, which reaches below the umbilicus. Where the intestines interfere with the downward expansion of the fundus the stomach retains the horizontal position which is characteristic of the contracted viscus.

Interior of the stomach.—When examined after death, the stomach is usually fixed at some stage of the digestive process. A common form is that shown in fig. 1171. When the viscus is laid open by a section through the plane of its two curvatures, it is seen to consist of two segments: (*a*) a large globular portion on the left and (*b*) a narrow tubular part on the right. The cardiac notch lies to the left of the abdominal part of the œsophagus: the projection of this notch into the cavity of the stomach increases as the organ

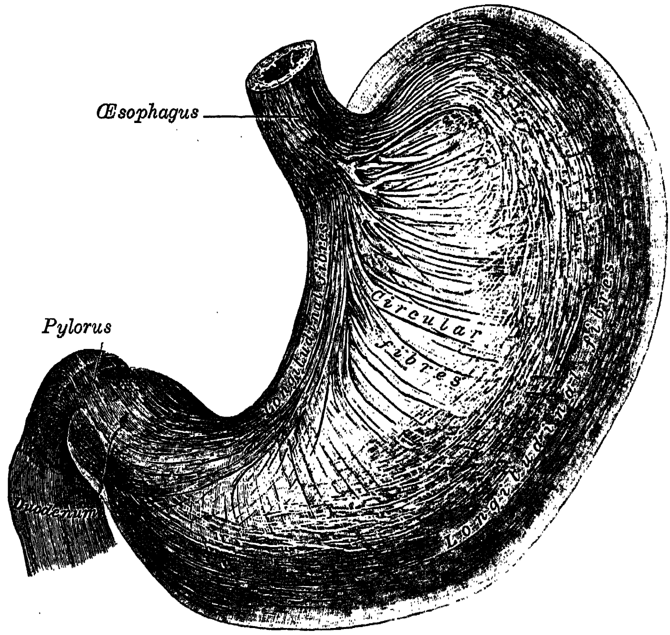
* *Archiv für Anatomie und Physiologie, anat. Abth.*, 1903.

† *Transactions of the Royal Society of Edinburgh*, vol. xlv. part i.

distends, and has been supposed to act as a valve preventing regurgitation into the œsophagus. The elevation corresponding to the incisura angularis is seen at the beginning, and the circular thickening of the pyloric sphincter at the end of the pyloric portion.

F. T. Lewis * has modelled the gastric epithelium in the human embryo, and has shown that a canal (named by him the *gastric canal*) extends along the lesser curvature from the cardiac orifice to the incisura angularis (fig. 1172), the distinctness of the canal being strikingly shown when the model is viewed from the inside. Jefferson † has brought forward radiographic evidence to show that such a canal exists in the adult. He found that in eighteen out of twenty-two cases examined whilst in the act of swallowing a mixture of oxychloride of bismuth and milk the fluid was confined to the lesser curvature. He is of the opinion that the oblique muscular coat of the stomach is so arranged that by its contraction it will cause a temporary cutting off of a canal along the lesser curvature.

FIG. 1173.—The longitudinal and circular muscular fibres of the stomach. Anterosuperior aspect. (Spalteholz.)



The *pyloric sphincter* is a muscular ring composed of a thickened portion of the circular layer of the muscular coat; this ring is covered with a reduplication of the mucous membrane. Some of the deeper longitudinal fibres turn in and interlace with the fibres of the sphincter.

Structure.—The wall of the stomach consists of four coats: serous, muscular, areolar and mucous, together with vessels and nerves.

The *serous coat* is derived from the peritoneum and covers the entire surface of the organ, excepting (*a*) along the greater and lesser curvatures at the lines of attachment of the greater and lesser omenta, where the two layers of peritoneum leave a small space, triangular on section, in which the vessels and nerves lie: and (*b*) a small area on the postero-inferior surface of the stomach, close to the cardiac orifice, where the stomach is in contact with the under surface of the Diaphragm.

The *muscular coat* (figs. 1173, 1174) is situated immediately beneath the serous covering, with which it is closely connected. It consists of three layers of unstriped muscular fibres: longitudinal, circular and oblique.

The *longitudinal fibres* are the most superficial, and are arranged in two sets. The first set consists of fibres continuous with the longitudinal fibres of the œsophagus; they radiate from the cardiac orifice and end proximal to the pyloric portion. The second set commences on the body of the stomach and passes to the right, its fibres becoming more thickly arranged as they approach the pylorus. Some of the more superficial fibres of this set pass on to the duodenum, but the deeper fibres dip inwards and interlace with the fibres of the pyloric sphincter.

* *American Journal of Anatomy*, vol. xiii.

† *Journal of Anatomy and Physiology*, vol. xlix.

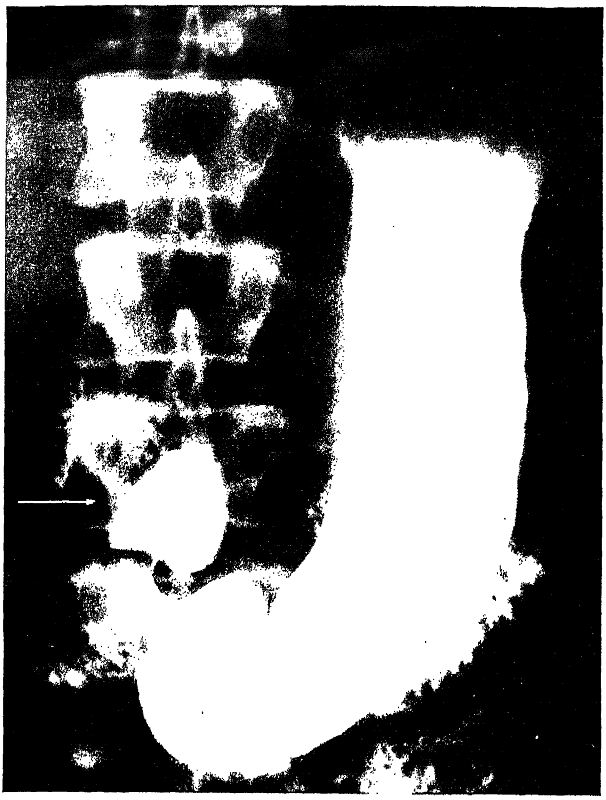


FIG. 1.—Radiograph of a normal stomach after a barium meal. The tone of the muscular wall is good and supports the weight of the column in the body of the organ. The arrow points to the duodenal cap, below which a gap in the barium indicates the position of the pylorus.

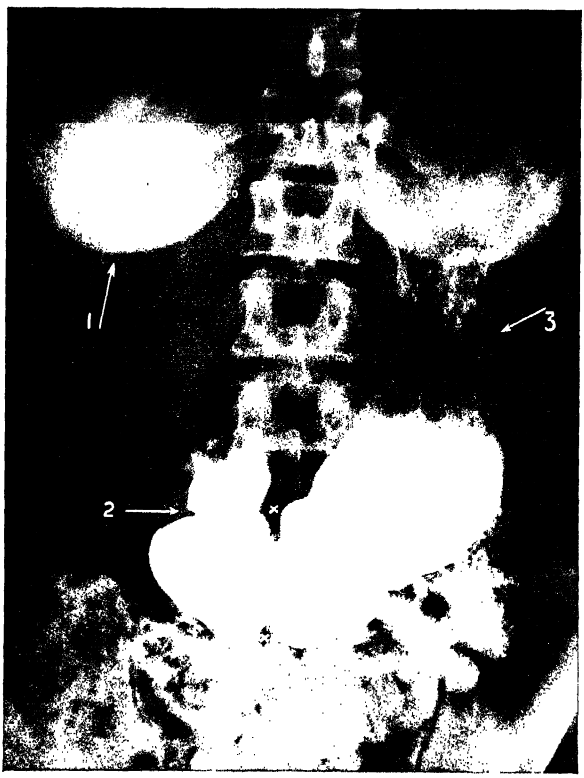


FIG. 2.—Radiograph of an atonic stomach after a barium meal. Note that this stomach contains the same amount of barium as the stomach in fig. 1. Arrow 1 points to the shadow of the right breast; arrow 2, to the pylorus; arrow 3, to the upper part of the body of the stomach, where longitudinal folds can be seen in the mucous membrane. XX marks a wave of peristalsis.

PLATE XVI

FIG. 1.—Radiograph of the small intestine after a barium meal. The 'feathery' appearance is due to the presence of the circular folds in the mucous coat.

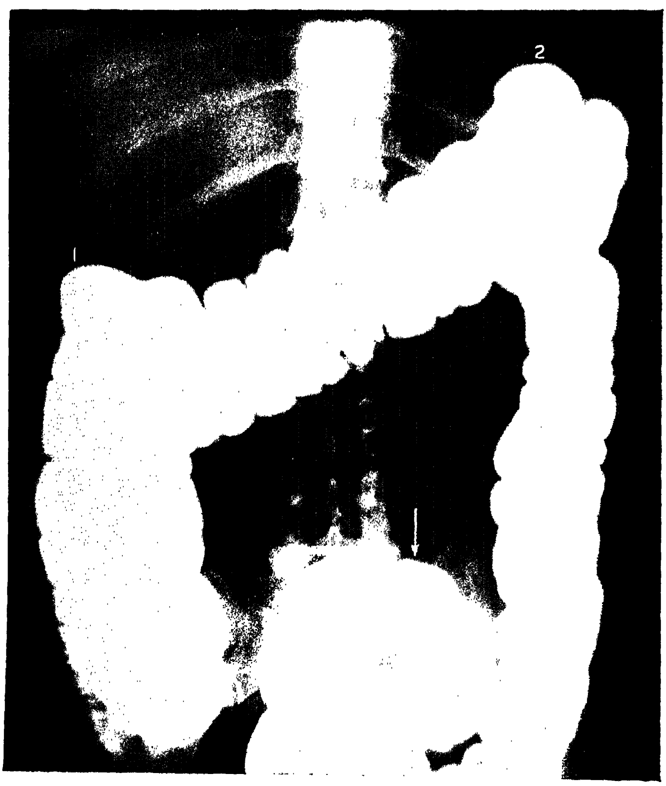
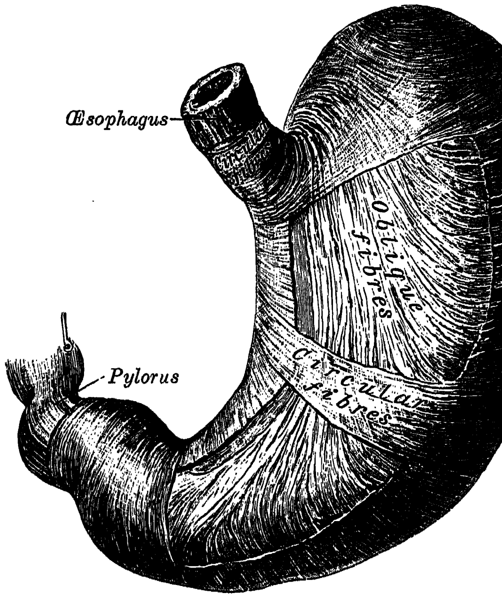


FIG. 2.—Radiograph of the large intestine after a barium enema. 1—right colic flexure; 2—left colic flexure. The arrow points to the pelvic colon. Note the sacculations of the gut, and the different levels of the two flexures.

The *circular fibres* form a uniform layer over the whole extent of the stomach beneath the longitudinal fibres. At the pylorus they are most abundant, and are there aggregated into a ring which forms the *pyloric sphincter*. The circular fibres of the stomach are con-

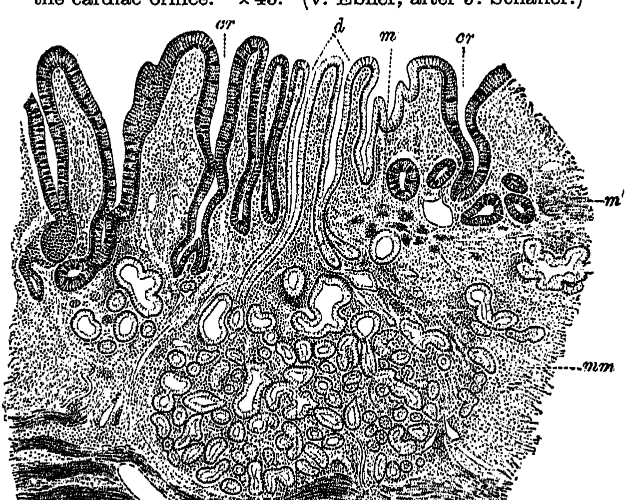
Fig. 1174.—The oblique muscular fibres of the stomach. Anterosuperior aspect. (Spalteholz.)



tinuous with the circular fibres of the œsophagus, but are sharply marked off from the circular fibres of the duodenum by a connective tissue septum.

The *oblique fibres*, internal to the circular layer, are limited chiefly to the body of the

Fig. 1175.—A section through the mucous membrane of a human stomach, near the cardiac orifice. ×45. (v. Ebner, after J. Schaffer.)



c. Cardiac glands. *d*. Their ducts. *cr*. Gland similar to the intestinal glands, with goblet cells. *mm*. Mucous membrane. *m*. Muscularis mucosæ. *m'*. Muscular tissue within the mucous membrane.

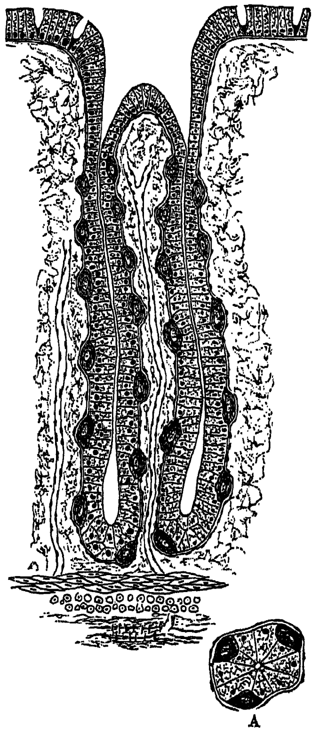
stomach. They sweep downwards from the incisura cardiaca and run more or less parallel with the lesser curvature. On the right they present a free and well-defined margin (fig. 1174); on the left they blend with the circular fibres.

The *areolar* or *submucous coat* consists of loose, areolar tissue, connecting the mucous and muscular layers.

The *mucous membrane* is thick and its surface is smooth, soft and velvety. In the fresh state it is of a pinkish tinge at the pyloric end, and of a red or reddish-brown colour over the rest of its surface. In infancy it is of a brighter hue, the vascular redness being more marked. It is thin at the cardiac extremity, but thicker towards the pylorus. During the contracted state of the organ it is thrown into numerous folds or rugæ which for the most part have a longitudinal direction, and are best marked towards the pyloric end of the stomach, and along the greater curvature (fig. 1171). These folds are obliterated when the organ is distended.

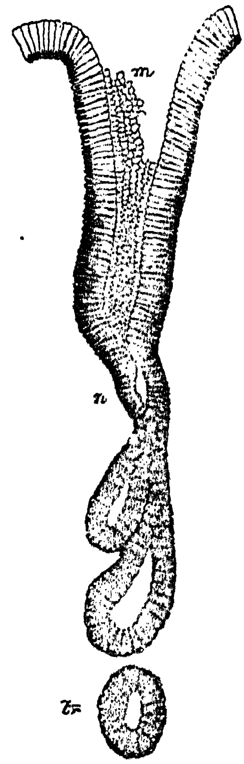
Structure of the mucous membrane.—When examined with a lens, the inner surface of the mucous membrane presents a peculiar, honeycomb appearance owing to the fact that it

FIG. 1176.—A fundus gland.



A. A transverse section through the gland.

FIG. 1177.—A pyloric gland, from a section through a dog's stomach. (Ebstein.) (From Quain's *Elements of Anatomy*, vol. ii. pt. i.)



m. Mouth. *n.* Neck. *tr.* A deep portion of a tubule cut transversely.

is covered with small, shallow depressions or alveoli, of a polygonal or hexagonal form, which vary from 0·12 mm. to 0·25 mm. in diameter. These are the ducts of the gastric glands, and at the bottom of each, one or more of the minute orifices of the gland-tubes may be seen. The surface of the mucous membrane is covered with a single layer of columnar epithelium with occasional goblet-cells. This epithelium commences very abruptly at the cardiac orifice, where there is a sudden transition from the stratified epithelium of the œsophagus. The epithelial lining of the gland-ducts is of the same character and is continuous with the general epithelial lining of the stomach.

The gastric glands are of three kinds: (*a*) *cardiac*, (*b*) *fundus* or *oxyntic*, and (*c*) *pyloric*. The *cardiac glands* (fig. 1184), few in number, occur close to the cardiac orifice. They are of two kinds: (1) simple tubular glands resembling those of the pyloric end of the stomach, but with short ducts; (2) compound racemose glands resembling the duodenal glands. The *fundus glands* (fig. 1176) are found in the body and fundus of the stomach; they are simple tubes, two or more of which open into a single duct. The duct is short, sometimes not amounting to more than one-sixth of the whole length of the gland. The epithelium of the fundus glands consists of (1) short columnar, glandular cells, known as the *chief* or *central cells*, which are responsible for the formation of pepsin, and (2) larger, oval cells, termed

parietal or *oxyntic cells*, which secrete the hydrochloric acid of the gastric juice. The latter lie between the chief cells and the basement-membrane, and stain deeply with eosin; they do not form a continuous layer, but occur at intervals and so give the tube a beaded appearance. They are connected with the lumen of the gland by fine channels which run in the substance of the cells. The *pyloric glands* (fig. 1177) are found in the pyloric portion of the stomach. Each consists of two or three short convoluted tubes opening into a funnel-shaped duct. The tubes are lined by cubical cells which are finely granular. Parietal or oxyntic cells are present in some of the pyloric glands. The ducts occupy about two-thirds of the depth of the mucous membrane.

Between the glands the mucous membrane consists of a connective tissue framework, and lymphoid tissue. In places, this latter tissue, especially in early life, is collected into little masses which resemble the solitary lymphatic nodules of the intestine, and are termed the *gastric lymphatic nodules*. They are not, however, so distinctly circumscribed as the solitary nodules. The mucous membrane is bounded on its deep surface by a thin stratum of involuntary muscular fibres (muscularis mucosæ), which in some parts consists only of a single longitudinal layer; in others of two layers, an inner circular and an outer longitudinal.

Vessels and Nerves.—The *arteries* supplying the stomach are: the left gastric branch of the cœliac artery, the right gastric and right gastro-epiploic branches of the hepatic artery, and the left gastro-epiploic and short gastric branches of the splenic artery. They supply the muscular coat, ramify in the submucous coat, and are finally distributed to the mucous membrane. The arrangement of the vessels in the mucous membrane is somewhat peculiar. The arteries break up at the deep ends of the gastric glands into a plexus of fine capillaries which run between the glands, anastomosing with each other, and ending in a plexus of larger capillaries, which surround the mouths of the glands, and also form hexagonal meshes around the gland-ducts. From these the *veins* arise, and pursue a straight course, between the glands, to the submucous tissue: they end either in the splenic and superior mesenteric veins, or directly in the portal vein. The *lymph vessels* are numerous; they consist of a superficial and a deep set, and pass to the lymph glands found along the two curvatures of the organ (p. 866). The *nerves* are the terminal branches of the right and left vagi, the former being distributed for the most part upon the back, and the latter for the most part upon the front part of the stomach. A great number of branches from the cœliac plexus of the sympathetic are also distributed to it. Nerve-plexuses are found in the submucous coat and between the layers of the muscular coat, as in the intestine. From these plexuses fibrils are distributed to the muscular tissue and the mucous membrane.

The Small Intestine [Intestinum Tenue]

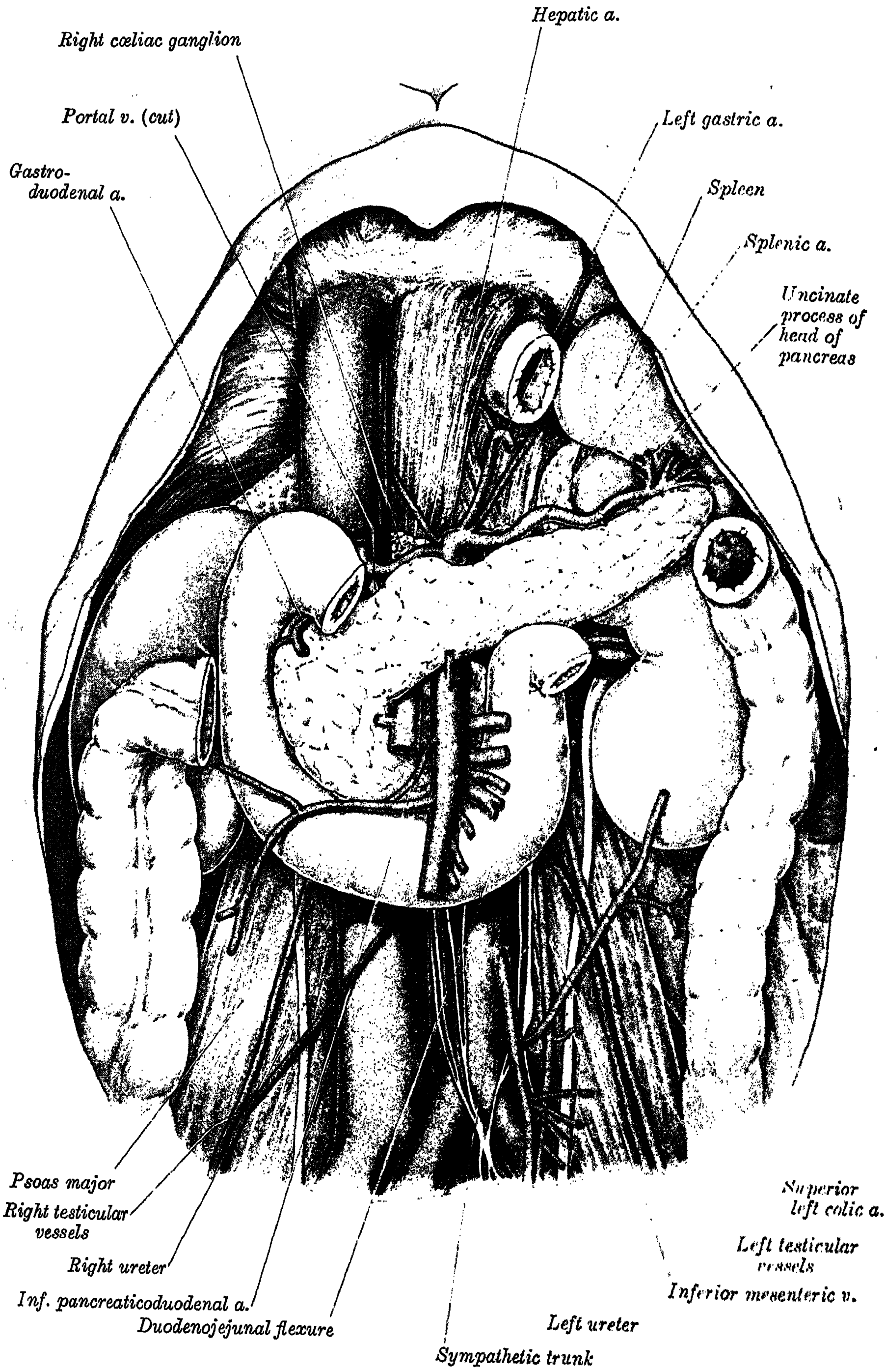
The **small intestine** is a convoluted tube, extending from the pylorus to the ileocolic valve, where it joins the large intestine. It is about 6·5 metres long, and gradually diminishes in diameter from its commencement to its termination. It is contained in the central and lower parts of the abdominal cavity and usually lies within the curve of the large intestine; it is in relation, in front, with the greater omentum and abdominal parietes; a portion of it extends down into the pelvis and lies in front of the rectum. The small intestine consists of (1) a short, curved portion which is devoid of a mesentery and is named the *duodenum*, and (2) a long, greatly coiled part which is attached to the posterior abdominal wall by the mesentery (p. 1313); the proximal two-fifths constitute the *jejunum* (*intestinum jejunum*), the distal three-fifths the *ileum* (*intestinum ileum*).

The **duodenum** (fig. 1178) is so named because its length is about equal to the breadth of twelve fingers (25 cm.). It is the shortest, widest and most fixed part of the small intestine; it has no mesentery, and is only partially covered with peritoneum. Its course presents a remarkably constant curve, somewhat of the shape of an imperfect circle, which encloses the head of the pancreas.

It begins at the pylorus, passes backwards, upwards and to the right, under cover of the quadrate lobe of the liver, to the neck of the gall-bladder, varying slightly in direction according to the degree of distention of the stomach; it then makes a sharp curve (*superior duodenal flexure*) and descends in front of the medial part of the right kidney, for a variable distance, generally to the level of the lower border of the body of the third lumbar vertebra. Here it makes a second bend (*inferior duodenal flexure*), and passes almost horizontally from right to left across the vertebral column, having a slight inclination upwards; it then ascends in front, or to the left, of the abdominal aorta for about 2·5 cm., and ends opposite the second lumbar vertebra in the jejunum. At its union with the jejunum it turns abruptly forwards, forming the *duodenojejunal flexure*. For descriptive purposes it is divided into first, second, third and fourth parts.

Relations.—The *first part* (superior portion) is about 5 cm. long, and is the most movable of the four portions; it begins at the pylorus, and ends at the

Fig. 1178.—A dissection to show the duodenum and pancreas.



neck of the gall-bladder. It is covered with peritoneum over the whole of its anterior aspect, but it is devoid of peritoneum posteriorly, *except near the pylorus*, where it takes a small part in the formation of the anterior wall of the lesser sac; the right part of the lesser omentum is attached to the upper border, and the

greater omentum to the lower border of the proximal half. It is in relation above and in front with the quadrate lobe of the liver and the gall-bladder; behind, with the gastroduodenal artery, the bile-duct and the portal vein, and below and behind, with the head and neck of the pancreas. It is in such close relation with the gall-bladder that it is usually found to be stained by bile after death, especially on its anterior surface.

The *second part* (descending portion) from 8 cm. to 10 cm. long, descends from the neck of the gall-bladder along the right side of the vertebral column as low as the lower border of the body of the third lumbar vertebra. It is crossed by the transverse colon, the posterior surface of which is connected to the duodenum by a small quantity of areolar tissue. The parts above and below the transverse colon are covered in front with peritoneum. It is in relation, in front, from above downwards, with the duodenal impression on the right lobe of the liver, the transverse colon, and the small intestine; behind, it has a variable relation to the front of the right kidney in the neighbourhood of its hilum, and is connected to it by loose areolar tissue; the right renal vessels, edge of the inferior vena cava, and Psoas major are also behind it. Its medial side is related to the head of the pancreas and the bile-duct; its lateral side, to the right colic flexure. The bile-duct and the pancreatic duct come into contact at the medial side of this part of the duodenum. The two ducts enter the wall of the gut obliquely, and there unite to form a short, dilated duct which is named the *ampulla of the bile duct.* The narrow, distal end of this ampulla opens on the summit of a papilla, termed the *duodenal papilla,* which is situated within the second part of the duodenum at the junction of its medial and posterior walls (figs. 1179, 1199), from 8 cm. to 10 cm. distal to the pylorus. The accessory pancreatic duct, when present, opens about 2 cm. proximal to the duodenal papilla.

The *third part* (horizontal portion), about 10 cm. long, begins at the right side of the lower border of the third lumbar vertebra and passes from right to left, with a slight inclination upwards, in front of the inferior vena cava, and ends in the fourth part in front of the abdominal aorta. Its anterior surface is covered with peritoneum, except near the median plane, where it is crossed by the superior mesenteric vessels and the root of the mesentery. Its posterior surface is uncovered by peritoneum, except towards its left extremity, where the posterior layer of the mesentery sometimes covers it to a variable extent. This surface rests upon the right ureter, the right Psoas major, the right testicular (or ovarian) vessels, the inferior vena cava and the abdominal aorta. The upper surface is in relation with the head of the pancreas; the lower, with the coils of the jejunum.

The *fourth part* (ascending portion), about 2·5 cm. long, ascends on or immediately to the left of the aorta, as far as the level of the upper border of the second lumbar vertebra, where it turns abruptly forwards [*duodenojejunal flexure*] and is continuous with the jejunum. It lies in front of the left sympathetic trunk, left Psoas major, the left renal and testicular vessels. Along its right border it gives attachment to the upper part of the root of the mesentery, the left layer of which is continued over its anterior surface and left side.

The first part of the duodenum, as stated above, possesses a range of movement, but the rest is relatively fixed, and is bound down to neighbouring viscera and the posterior abdominal wall.

The fourth part of the duodenum and the duodenojejunal flexure are fixed by the Suspensory muscle of the duodenum, which arises from the right crus of the Diaphragm, close to the right margin of the œsophagus. It passes downwards and slightly forwards in close relation with the cœliac artery (sometimes dividing to enclose this vessel) and is attached to the posterior surface of the upper part of the duodenojejunal flexure, many fibres being continued into the mesentery.* This muscle consists of three parts, viz. an upper of striped muscular fibres, an intermediate elastic tendon, and a lower of unstriped muscular fibres.

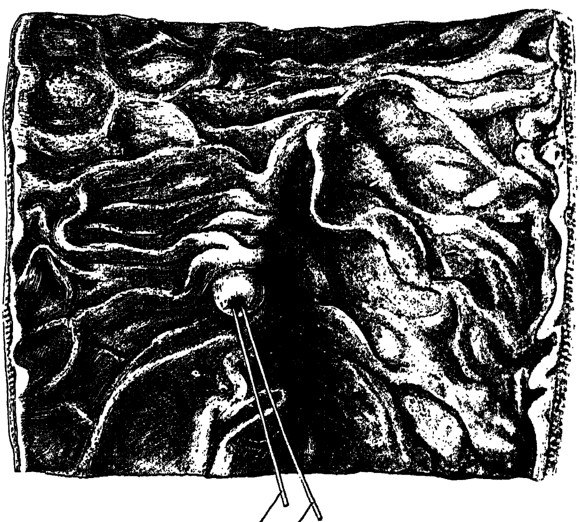
Vessels and Nerves.—The *arteries* supplying the duodenum are the right gastric and superior pancreaticoduodenal branches of the hepatic, and the inferior pancreaticoduodenal

* A. Low, *Journal of Anatomy and Physiology,* vol. xlii.

branch of the superior mesenteric. One, sometimes two, small branches descend from the hepatic artery as it lies in the lesser omentum and supply a limited area near the termination of the first part. The *veins* end in the splenic, superior mesenteric and portal veins. The *nerves* are derived from the cœliac plexus.

The rest of the small intestine, about 6 metres long, extends from the duodenojejunal flexure to the ileocolic valve, where it ends in the cæcum of the large intestine ; it is arranged in a series of coils or loops which are attached to the posterior abdominal wall by the mesentery. This part of the gut is completely covered with the peritoneum, except for a narrow strip along its mesenteric border, where the two layers of the mesentery diverge from each other to enclose it. It is divided into jejunum and ileum, the former name being given to the upper two-fifths and the latter to the lower three-fifths. There is no morphological line of distinction between these two parts, and the division is arbitrary ; but at the same time the character of the intestine gradually undergoes a change

FIG. 1179.—The interior of the second part of the duodenum, showing the duodenal papilla.



from the beginning of the jejunum to the end of the ileum, so that portions of the bowel taken from these two situations present characteristic differences.

The **jejunum** (intestinum jejunum) has a diameter of about 4 cm., and is thicker, redder and more vascular than the ileum. The circular folds (p. 1328) of its mucous membrane are large and thickly set, and its villi surpass those of the ileum in size. The aggregated lymphatic nodules (p. 1330) are almost absent in the upper part of the jejunum ; in the lower part they are less frequently found than in the ileum, and are smaller and tend to assume a circular form. When the jejunum is grasped between the finger and thumb the circular folds can be felt through the wall of the gut ; as these folds are absent from the lower part of the ileum, it is possible in this way to distinguish the upper from the lower part of the small intestine.

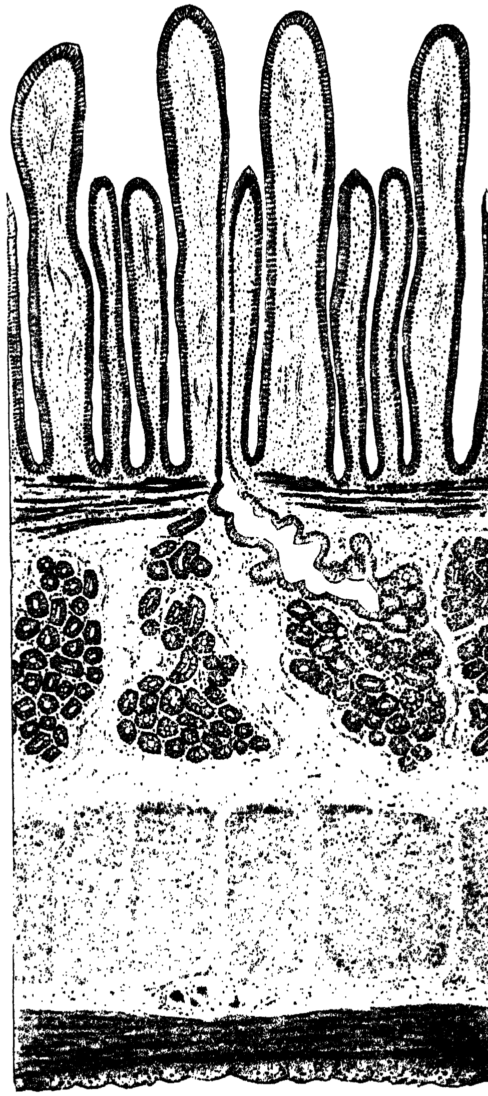
For the most part the jejunum lies in the umbilical region, but it may extend into any of the surrounding areas. The first coil occupies a recess between the left part of the transverse mesocolon and the anterior surface of the left kidney (p. 1345).

The **ileum** (intestinum ileum) has a diameter of 3·5 cm., and its coats are thinner than those of the jejunum. A few circular folds are present in the upper part of the ileum, but they are small and disappear almost entirely towards its lower end ; the aggregated lymphatic nodules are, however, larger and more numerous than in the jejunum. For the most part the ileum is situated in the hypogastric and pelvic regions. The terminal part of the ileum usually lies in

the pelvis, from which it ascends over the right Psoas major and right iliac vessels ; it ends in the right iliac fossa by opening into the medial side of the cæcum.

The jejunum and ileum are attached to the posterior abdominal wall by an extensive fold of peritoneum, termed the *mesentery,* which allows of very free

FIG. 1180.—A section through the duodenum of a cat. ×60. (From Sharpey-Schafer's *Essentials of Histology.*)



movement, so that each coil can accommodate itself to changes in form, and position. The mesentery is fan-shaped ; its vertebral border or root, about 15 cm. long, is attached to the posterior abdominal wall along a line running from the left side of the body of the second lumbar vertebra to the right sacro-iliac joint, and crossing successively the third part of the duodenum, the aorta, the inferior vena cava, the right ureter, and right Psoas major (fig. 1161). Its average breadth from the vertebral to the intestinal border is about 20 cm., but is greater in the middle than at its upper and lower ends ; according to Lockwood the breadth of the mesentery tends to increase as age advances. The two layers of the mesentery contain the jejunum, ileum, the jejunal and ileal

branches of the superior mesenteric blood-vessels, nerves, lacteals, and lymph glands, together with a variable amount of fat (p. 1314).

Meckel's diverticulum.—This is a pouch which projects from the lower part of the ileum in about 2 per cent. of subjects. Its average position is about 1 metre above the ileocolic valve, and its average length about 5 cm. Its calibre is generally similar to that of the ileum, and its blind extremity may be free or may be connected with the abdominal wall or with some other portion of the intestine by a fibrous band. It represents the persistent proximal part of the vitello-intestinal duct, which connects the yolk-sac and the primitive digestive tube in early fœtal life (pp. 71, 168).

Structure.—The wall of the small intestine (fig. 1180) is composed of four coats: serous, muscular, areolar and mucous.

The *serous* coat is formed of peritoneum.

The *muscular coat* is thicker in the upper than in the lower part of the small intestine; it consists of an external longitudinal and an internal circular layer of non-striped muscular fibres. The *longitudinal layer* is thin; the *circular layer* is thick, and composed of fibres of considerable length.

The *areolar* or *submucous coat* unites the mucous and muscular layers. It consists of loose, areolar tissue containing blood-vessels, lymph vessels and nerves.

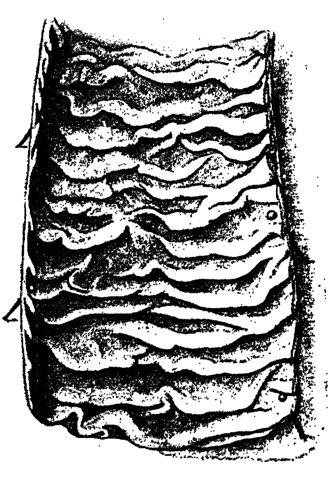
The *mucous membrane* is thick and highly vascular in the upper part of the small intestine, but thinner and less vascular in the lower part. It consists of the following structures: next to the areolar or submucous coat there is the *muscularis mucosæ*, which consists of an outer longitudinal and inner circular layer of unstriped muscular fibres; internal to the muscularis mucosæ there is a quantity of retiform tissue, enclosing in its meshes lymph-corpuscles, and in which the blood-vessels and nerves ramify; lastly, a basement membrane, supporting a single layer of tall columnar cells. The cells are granular in appearance, and each possesses a clear oval nucleus. Their superficial and unattached ends present a distinct layer of highly refracting material, marked by vertical striæ (the *striated border*). Goblet-cells occur at intervals in the epithelial layer.

The following structures are contained within or belong to the mucous membrane:

Circular folds.	Duodenal glands.
Villi.	Solitary lymphatic nodules.
Intestinal glands.	Aggregated lymphatic nodules.

The **circular folds** (fig. 1181) are large transverse folds of mucous membrane which project into the lumen of the bowel. They are composed of reduplications of the mucous membrane, the two layers of the fold being bound together by submucous tissue; unlike the folds in the stomach they are permanent, and are not obliterated when the intestine is distended. The majority extend transversely round the intestine for about one-half or two-thirds of its circumference, but some form complete circles, some bifurcate and join adjacent folds, and others have a spiral direction; the latter usually extend a little more than once round the bowel, but occasionally two or three times. The larger folds are about 8 mm. in depth at their broadest part; but the greater number are of smaller size. The larger and smaller folds alternate with each other. Circular folds are not found at the commencement of the duodenum, but begin to appear about 2·5 or 5 cm. beyond the pylorus. Distal to the point where the bile- and pancreatic ducts enter the duodenum, they are very large and closely approximated. In the upper one-half of the jejunum they are large and numerous, but from this point, down to the middle of the ileum, they diminish considerably in size. In the lower part of the ileum they are almost entirely absent; hence the comparative thinness of this portion of the intestine, as compared with the duodenum and jejunum. The circular folds retard the passage of the food and afford an increased surface for absorption (Pl. XVI, fig. 1).

Fig. 1181.—The interior of a portion of the upper part of the jejunum, showing the circular folds.



The **intestinal villi** are highly vascular processes, just visible to the naked eye; they project from the mucous membrane of the whole of the small intestine, and give to its surface a velvety appearance. They are large and numerous in the duodenum and jejunum, but are smaller and fewer in the ileum.

Structure of the villi (figs. 1182, 1183).—The essential parts of a villus are: the lacteal

vessel, the blood-vessels, the epithelium, the basement-membrane and the muscular tissue of the mucosa, all being supported and held together by retiform tissue.

The *lacteals* are in some cases double, and in some animals multiple, but usually there is a single vessel. Situated in the axis of the villus, each commences by a dilated blind extremity near to, but not quite at, the summit of the villus. The wall is composed of a single layer of endothelial cells.

The *muscular fibres* are derived from the muscularis mucosæ, and are arranged in bundles around the lacteal vessel, extending from the base to the summit of the villus, and giving off, laterally, individual muscle-cells, which are enclosed by the reticulum, and by it are attached to the basement-membrane and to the lacteal.

The *blood-vessels* (fig. 1184) form a plexus under the basement-membrane, and are enclosed in the reticular tissue.

These structures are surrounded by the *basement-membrane*, which is made up of a layer of endothelial cells, and upon this is placed a layer of *columnar epithelium*, the

FIG. 1182.—A vertical section through a villus of the small intestine of a dog. × 80.

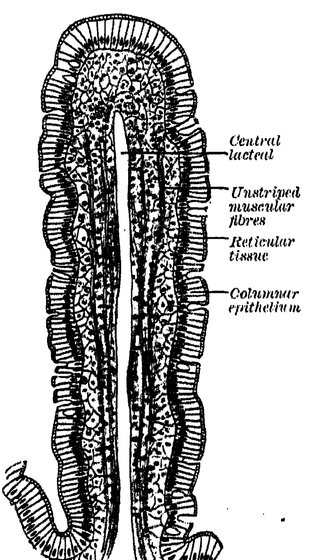
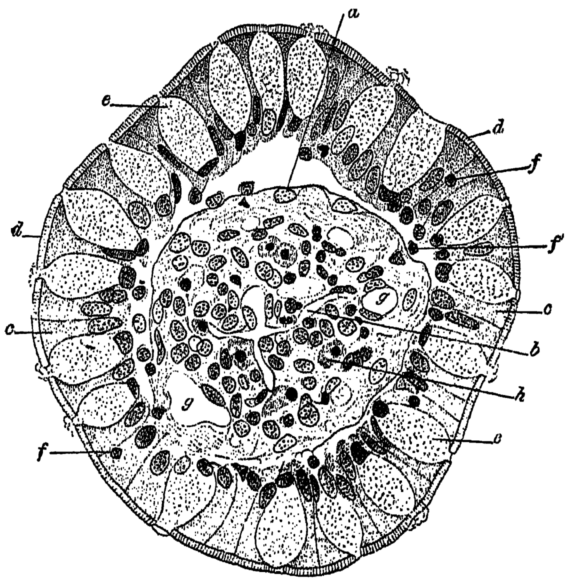


FIG. 1183.—A transverse section through a villus of the human intestine. × 350. (v. Ebner.)



a. Basement-membrane, here somewhat shrunken away from the epithelium. *b*. Lacteal. *c*. Columnar epithelium; *d*. its striated border. *e*. Goblet-cells. *f*. Leucocytes in epithelium. *f'*. Leucocyte below epithelium. *g*. Blood-vessels. *h*. Muscle-cells cut across.

characteristics of which have been described above. The *retiform tissue* forms a network (fig. 1183) in the meshes of which a number of leucocytes are found.

The **intestinal glands** (fig. 1185) are found in considerable numbers over every part of the mucous membrane of the small intestine. They are simple tubular glands, arranged perpendicularly to the surface, upon which they open by small circular apertures. Their orifices may be seen with the aid of a lens as minute dots scattered between the villi. Their walls are thin, consisting of a basement-membrane lined with columnar epithelium, and covered on their exterior with capillary vessels. The deeper cells, especially in the duodenal glands, contain granules which stain characteristically with phosphotungstic haematoxylin and are termed *granules of Paneth*.

The **duodenal glands** are limited to the duodenum (fig. 1180), and are found in the submucous areolar tissue. They are largest and most numerous near the pylorus, forming an almost complete layer in the first part, and upper half of the second part, of the duodenum; beyond this they gradually diminish in number and disappear at the junction of the duodenum and jejunum. They are small, compound, acinotubular glands, each consisting of a number of alveoli lined with short columnar epithelium and opening by a duct on the inner surface of the intestine.

The **solitary lymphatic nodules** are found scattered throughout the mucous membrane of the small intestine, but are most numerous in the lower part of the ileum. Their free surfaces are covered with rudimentary villi, except at the summits, and each nodule is surrounded by the openings of the intestinal glands. Each consists of a dense, interlacing, retiform tissue closely packed with lymph-corpuscles, and permeated by an abundant, capillary network.

The interspaces of the retiform tissue are continuous with larger lymph-spaces which surround the nodule, and by this means they are enabled to communicate with the lacteal

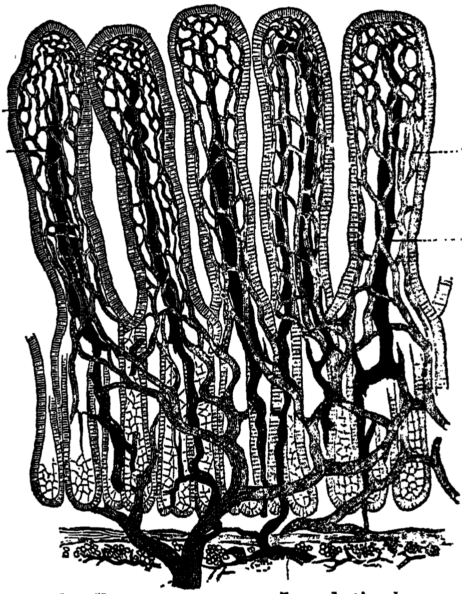
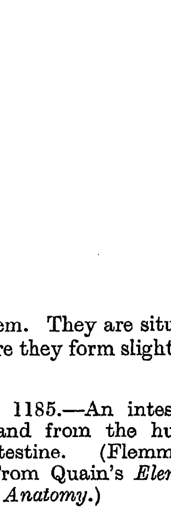


FIG. 1184.—The villi of the small intestine, showing the blood-vessels and the lymph vessels. (Cadiat.)

system. They are situated partly in the submucous tissue, and partly in the mucous coat, where they form slight projections of its epithelial layer.

FIG. 1185.—An intestinal gland from the human intestine. (Flemming.) (From Quain's *Elements of Anatomy*.)

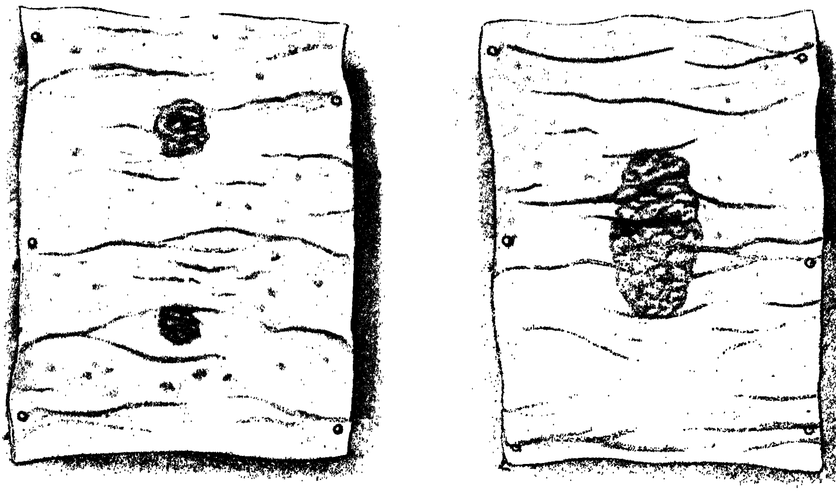


The **aggregated lymphatic nodules** (figs. 1186, 1187) form circular or oblong patches, from twenty to thirty in number, and varying in length from 2 cm. to 10 cm. Like the other collections of lymphoid tissue in the body, they are best marked in the young subject, become indistinct in middle age, and usually disappear altogether in advanced life. They are largest and most numerous in the ileum. In the lower part of the jejunum they are small, circular and few in number. They are occasionally seen in the duodenum. They are placed lengthwise in the intestine, and are situated in the portion of the tube most distant from the attachment of the mesentery. Each patch is formed of a group of solitary lymphatic nodules covered with columnar epithelium; the patches do not, as a rule, possess villi on their free surfaces. They are freely supplied with blood-vessels, which form an abundant plexus around each nodule and give off fine branches to permeate the lymphoid tissue in the interior of the nodule. The plexuses of lymph vessels are especially abundant around these patches.

Vessels and Nerves.—The jejunum and ileum are supplied by the superior mesenteric artery, the jejunal and ileal branches of which, having reached the attached border of the bowel, run between the serous and muscular coats. From these vessels numerous branches are given off, which pierce the muscular coat, supplying it and forming an intricate plexus in the submucous tissue. From this plexus minute vessels pass to the glands and villi of the mucous membrane. The anastomoses between the terminal intestinal branches are by no means free, and there is a distinct tendency for the alternate vessels to be distributed to opposite sides of the gut. The *veins* have a course and arrangement similar to the arteries. The *lymph vessels* of the small intestine [lacteals] are arranged in two sets, viz. those of the mucous membrane and those of the muscular coat. The lymph vessels of the villi commence in these structures in the manner

described on p. 1329. They form an intricate plexus in the mucous and submucous tissue, being joined by the lymph vessels from the lymph-spaces at the bases of the solitary nodules, and from there pass to larger vessels at the mesenteric border of the

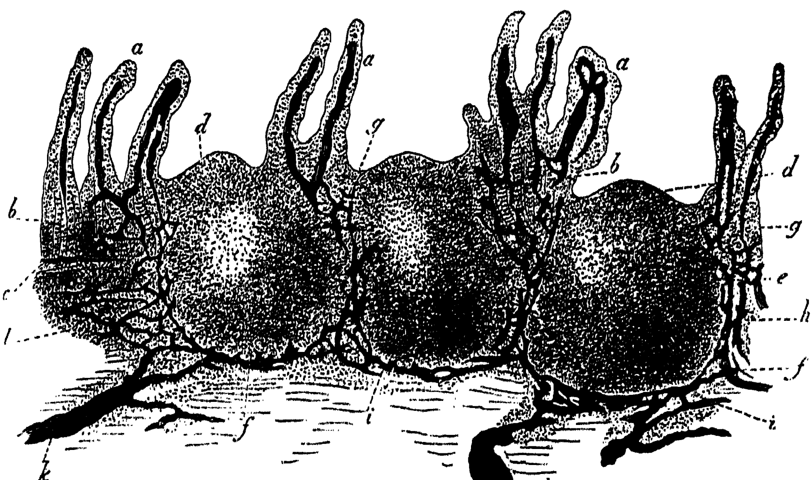
FIG. 1186.—Aggregated lymphatic nodules. A, from the upper part, and B, from the lower part, of the ileum.



A B

gut. The lymph vessels of the muscular coat are situated to a great extent between the two layers of muscular fibres, where they form a close plexus; throughout their course they communicate freely with those from the mucous membrane, and open in

FIG. 1187.—A vertical section through a human aggregated lymphatic nodule, injected through the lymphatic vessels.



a. Villi with their lacteals. *b*. Intestinal glands. *c*. Muscularis mucosæ. *d*. Cupula or apex of solitary lymphatic nodule. *e*. Intermediate zone of nodule. *f*. Base of nodule. *g*. Points of exit of the lacteals from the villi, and entrance into the true mucous membrane. *h*. Retiform arrangement of the lymph vessels in the internodular zone. *i*. Course of the latter at the base of the nodule. *k*. Confluence of the lymph vessels in the submucous tissue. *j*. Follicular tissue of the latter.

the same manner as these into the origins of the lacteal vessels at the attached border of the gut.

The *nerves* of the small intestine are derived from the vagus and splanchnic nerves through the cœliac ganglia and the plexuses around the superior mesenteric artery. They run to the

myenteric plexus (*Auerbach's plexus*) of nerves and ganglia, situated between the circular and longitudinal layers; from this plexus filaments are distributed to the muscular coats of the intestine. From the myenteric plexus a secondary plexus, termed the *plexus of the submucosa* (*Meissner's plexus*), is derived, and is formed by branches which have perforated the circular muscular layer. This plexus also contains ganglia from which the nerve-fibres pass to the muscularis mucosæ and to the mucous membrane. The nerve-bundles of the submucous plexus are finer than those of the myenteric plexus.

Keith states that 'Auerbach's plexus is not composed simply of ganglionic cells and nerve-fibres; it contains numerous other cells to which Kölliker called attention, and which may be described as Kölliker's cells. These cells have small bodies which send out numerous branched processes, and differ from pure sheath-cells in staining reaction and structure. It is through these cells that Auerbach's tissue is linked up with the musculature of the bowel. The nerve-fibres which former authors have described as distributed to the muscular and other coats of the bowel are probably sensory in nature. Sections of the developing bowel show that the outer and inner muscular coats are developed from a germinal layer situated between them. Auerbach's plexus represents the residue of the germinal or developmental intermediate layer. Probably the ganglionic cells may be of central origin, but the cells of Kölliker are apparently undifferentiated muscle-cells.' He adds that in point of development Auerbach's plexus is similar in origin to that of the atrioventricular bundle, and is of opinion that they are homologous.*

The Large Intestine [Intestinum Crassum]

The **large intestine** extends from the end of the ileum to the anus, and is about 1·5 metres long. Its calibre is largest at its commencement at the cæcum, and gradually diminishes as far as the rectum, where there is a dilatation of considerable size just above the anal canal. In appearance, structure, size and arrangement it presents certain differences from the small intestine. (1) It has a greater calibre. (2) For the most part, it is more fixed in position. (3) Its longitudinal muscular fibres do not form a continuous layer round the gut but are arranged in three longitudinal bands or *tæniæ coli*. (4) Since these tæniæ are shorter than the circular muscular coat, the colon is puckered and sacculated. (5) Little, peritoneum-covered, fatty projections, termed *appendices epiploicæ*, are found scattered over the free surface of the whole of the large intestine, with the exceptions of the cæcum, the vermiform appendix and the rectum.

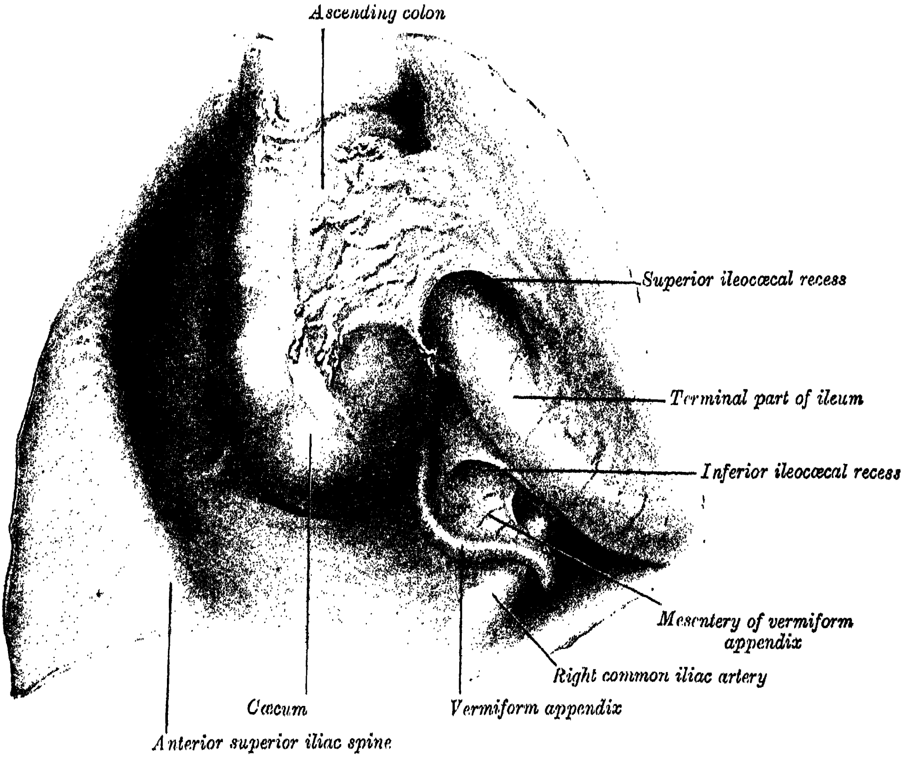
In its course the large intestine describes an arch which usually encloses the convolutions of the small intestine. It commences in the right iliac region, in a dilated part, termed the *cæcum* (fig. 1188). It ascends through the right lumbar and hypochondriac regions to the under surface of the liver; here it bends [the *right colic flexure*] (fig. 1178) to the left, and, curving with a downward and a forward convexity, passes, as the *transverse colon*, across the abdomen to the left hypochondriac region; it then bends again [the *left colic flexure*] (fig. 1178), and descends through the left lumbar and iliac regions to the pelvis, where it forms a loop called the *pelvic colon* (fig. 1191); from this it is continued along the lower part of the posterior wall of the pelvis to the anus. It is divided into the cæcum, the colon, the rectum and the anal canal.

The **cæcum** (fig. 1188), which is the commencement of the large intestine, lies in the right iliac fossa. It is a large sac which has a blind lower end but is continuous above with the ascending colon, and at the point where the one passes into the other the ileum opens into the large intestine from the medial side. Its average length is about 6 cm. and its breadth about 7·5 cm. It is situated in the right iliac fossa above the lateral half of the inguinal ligament: it rests on the Iliacus, from which it is separated by its covering fascia and the lateral cutaneous nerve of the thigh, and on Psoas major. In front it is usually in contact with the anterior abdominal wall, but the greater omentum, and, if the cæcum is empty, some coils of small intestine, may lie in front of it. As a rule, it is entirely enveloped by peritoneum, but in about 5 per cent. of cases (Berry) the peritoneal covering is incomplete, the upper part of the posterior surface being uncovered, and connected to the iliac fascia by areolar tissue. The cæcum enjoys a considerable amount of movement, so that it may become herniated down the right inguinal canal, and it has occasionally been found in an inguinal hernia on the left side.

* *Proceedings of the Anatomical Society of Great Britain and Ireland*, January 1915.

The cæcum varies in shape, but, according to Treves, it may be classified under one of four types. In early fœtal life it is short, conical, and broad at the base, with its apex turned upwards and medially towards the ileocolic junction. It then resembles the cæcum of the mangabey monkey. As the fœtus grows, the cæcum increases in length more than in breadth, so that it forms a longer tube than in the primitive form and lacks the broad base, but still has the same inclination of the apex towards the ileocolic junction. This form is seen in the spider monkey. As development goes on, the lower part of the tube ceases to grow and the upper part becomes greatly increased, so that at birth the narrow vermiform appendix hangs from the apex of a conical cæcum. This is the infantile form, and as it persists throughout life in about 2 per cent. of subjects, it was regarded by Treves as the *first* of his four types of human cæca. The cæcum is conical and the appendix rises from its apex. The three tæniæ coli (p. 1340) start from the appendix and are equidistant from each other. In the *second* type, the conical cæcum has become quadrate by the outgrowth of a

FIG. 1188.—The terminal part of the ileum, the cæcum and the vermiform appendix. Viewed from in front.

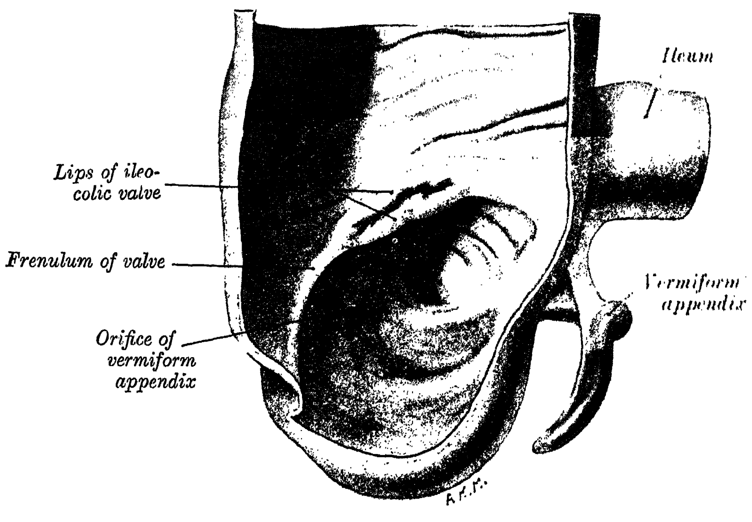


saccule on each side of the anterior tænia. These saccules are of equal size, and the appendix arises from the depression between them, instead of from the apex of a cone. This type is found in about 3 per cent. of subjects. The *third* type is the normal type for man. Here the two saccules, which in the second type were uniform, have grown at unequal rates: the right with greater rapidity than the left. In consequence of this an apparently new apex has been formed by the downward growth of the right saccule, and the original apex, with the appendix attached, is pushed over to the left towards the ileocolic junction. The three tæniæ still start from the base of the vermiform process, but they are now no longer equidistant from each other, because the right saccule has grown between the anterior and posterolateral tæniæ, pushing them over to the left. This type occurs in about 90 per cent. of subjects. The *fourth* type is merely an exaggerated condition of the third; the right saccule is still larger, and at the same time the left saccule has become atrophied, so that the original apex of the cæcum, with the vermiform appendix, is close to the ileocolic junction, and the anterior tænia courses medially to the same situation. This type is present in about 4 per cent. of subjects.

The ileocolic valve (fig. 1189).—The lower end of the ileum opens into the medial and posterior aspect of the large intestine, at the point of junction of the cæcum with the colon. The opening is provided with a valve, consisting of two

segments or lips, which project into the lumen of the large intestine. If the intestine has been inflated and dried, the lips are of a semilunar shape. The upper lip, nearly horizontal in direction, is attached by its convex border to the line of junction of the ileum with the colon ; the lower lip, the longer and more concave, is attached to the line of junction of the ileum with the cæcum. At the ends of the aperture the two segments of the valve coalesce, and are continued as narrow membranous ridges around the canal for a short distance, forming the *frenula* of the valve. The left or anterior end of the aperture is rounded ; the right or posterior is narrow and pointed. In the fresh condition, or in specimens which have been hardened *in situ*, the circular muscular coat of the ileum is thickened to form a sphincter-like valve, while the lips of the valve project as thick folds into the lumen of the cæcum, and the opening between them may present the appearance of a slit or may be somewhat oval in shape.

FIG. 1189.—The interior of the cæcum and the lower end of the ascending colon, showing the ileocolic valve.



Each lip of the valve is formed by a reduplication of the mucous membrane and of the circular muscular fibres of the intestine, the longitudinal fibres and peritoneum being continued uninterruptedly from the small to the large intestine.

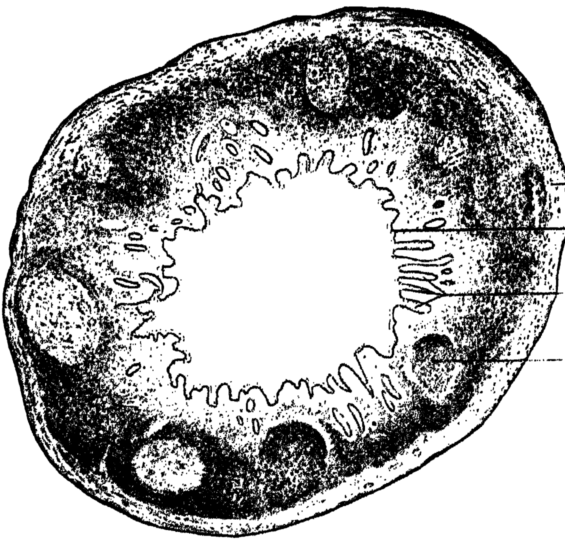
The surfaces of the valve directed towards the ileum are covered with villi and present the characteristic structure of the mucous membrane of the small intestine ; while those turned towards the large intestine are destitute of villi and marked with the orifices of the numerous tubular glands peculiar to the mucous membrane of the large intestine. It was formerly maintained that this valve prevented reflux from the cæcum into the ileum, but in all probability it acts as a sphincter round the end of the ileum and prevents the contents of the ileum from passing too quickly into the cæcum ; the valve is kept in a condition of tonic contraction by impulses which reach it through the splanchnic nerves.

The **vermiform appendix** (fig. 1188, Pl. XVII) is a long, narrow, worm-shaped tube, which springs from the posteromedial wall of the cæcum, 2 cm. or less below the end of the ileum, and may occupy one of several positions*: (*a*) it may lie behind the cæcum and the lower part of the ascending colon (*postcæcal and retrocolic*),

* R. J. Gladstone and Cecil P. G. Wakeley (*British Journal of Surgery*, vol. xi. No. 43, 1924) examined the positions of the vermiform appendix in 3000 subjects and found it to be postcæcal and retrocolic in 69·2 per cent., pelvic in 27·5 per cent., subcolic in 1·86 per cent., and pre- and postileal in 1·4 per cent. These percentages differ very markedly from those given by other observers.

(*b*) it may hang down over the brim of the pelvis (*pelvic* or *descending*), (*c*) it may lie below the cæcum (*subcolic*), (*d*) it may lie in front of the terminal part of the ileum and may then be in contact with the anterior abdominal wall, and (*e*) it may lie behind the terminal part of the ileum. It varies from 2 cm. to 20 cm. in length, the average being about 9 cm. It is connected by a short mesentery to the lower part of the mesentery of the ileum. This fold, in the majority of cases, is more or less triangular in shape, and as a rule extends along the entire length of the tube. The appendicular artery lies between the two layers of the appendicular mesentery, and close to its free margin. The canal of the vermiform appendix is small, and communicates with the cæcum by an orifice which is placed below and a little behind the ileocolic opening. The orifice is sometimes guarded by a semilunar valve formed by a fold of mucous membrane.

FIG. 1190.—A transverse section through the human vermiform appendix. ×20.



Structure.—The coats of the vermiform appendix are the same as those of the intestine: serous, muscular, submucous and mucous. The *serous* coat forms a complete investment for the tube, except along the narrow line of attachment of its mesentery. The *longitudinal muscular fibres* do not form three bands as in the greater part of the large intestine, but invest the whole organ, except at one or two points where both the longitudinal and circular layers are deficient, so that the peritoneal and submucous coats are contiguous over small areas. The *circular muscular fibres* form a thicker layer than the longitudinal fibres, and are separated from them by a small amount of connective tissue. The *submucous* coat is well developed, and contains a large number of masses of lymphoid tissue which cause the mucous membrane to bulge into the lumen and so render the latter of small size and irregular shape. The *mucous membrane* is lined with columnar epithelium and resembles that of the rest of the large intestine, but the intestinal glands are fewer in number (fig. 1190).

The **colon** is divided into four parts: the ascending, transverse, descending and pelvic.

The **ascending colon**, about 15 cm. long, is smaller in calibre than the cæcum. It begins at the cæcum, and ascends to the under surface of the right lobe of the liver, where it is lodged in a shallow depression, termed the colic impression; here it bends abruptly forwards and to the left, forming the *right colic flexure* (fig. 1178). It is retained in contact with the posterior wall of the abdomen by the peritoneum, which covers its sides and anterior surface, its posterior surface being connected by loose areolar tissue with the Iliacus, iliolumbar ligament, Quadratus lumborum, aponeurotic origin of Transversus abdominis, and with the front of the lower and lateral part of the right kidney. The lateral cutaneous nerve of the thigh, the fourth lumbar artery (as a rule) and, sometimes, the ilio-inguinal and iliohypogastric nerves cross behind it. Sometimes it is com-

pletely invested with peritoneum, and it then possesses a distinct but narrow mesocolon.* It is in relation, in front, with the convolutions of the ileum, the right edge of the greater omentum and the abdominal parietes.

The *right colic flexure* comprises the terminal part of the ascending colon and the commencement of the transverse colon, which turns downwards, forwards and to the left. Behind, it is in relation with the lower and lateral part of the anterior surface of the right kidney. Above and anterolaterally, it is related to the right lobe of the liver; anteromedially, to the second part of the duodenum and the fundus of the gall bladder.

The **transverse colon** (fig. 1168), about 50 cm. long, begins at the right colic flexure, in the right hypochondriac region, and, passing across the abdomen into the left hypochondriac region, curves sharply on itself, downwards and backwards, beneath the lower end of the spleen, forming the *left colic flexure*. In its course across the abdomen it describes an arch, the concavity of which is usually directed backwards and upwards; towards its splenic end there is often an abrupt U-shaped curve which may descend lower than the main curve. The precise position occupied by the transverse colon is difficult to define, for it not only shows variations from individual to individual but its position varies in the same individual from time to time. Very commonly it lies in the lower umbilical or upper hypogastric region, but it is often found at a higher level, especially in formalin-hardened subjects. The posterior surface of its right extremity is devoid of peritoneum, and is attached by areolar tissue to the front of the second part of the duodenum and the head of the pancreas. Between the head of the pancreas and the left colic flexure the transverse colon is almost completely invested by peritoneum, and is connected to the anterior border of the pancreas by the *transverse mesocolon*. It is in relation, by its upper surface, with the liver and gall-bladder, the greater curvature of the stomach, and the lateral end of the spleen; by its under surface, with the small intestine; by its anterior surface with the anterior layers of the greater omentum and the abdominal parietes; its posterior surface is in relation with the second portion of the duodenum, the head of the pancreas, the upper end of the mesentery, the duodenojejunal flexure and some of the coils of the jejunum and ileum.

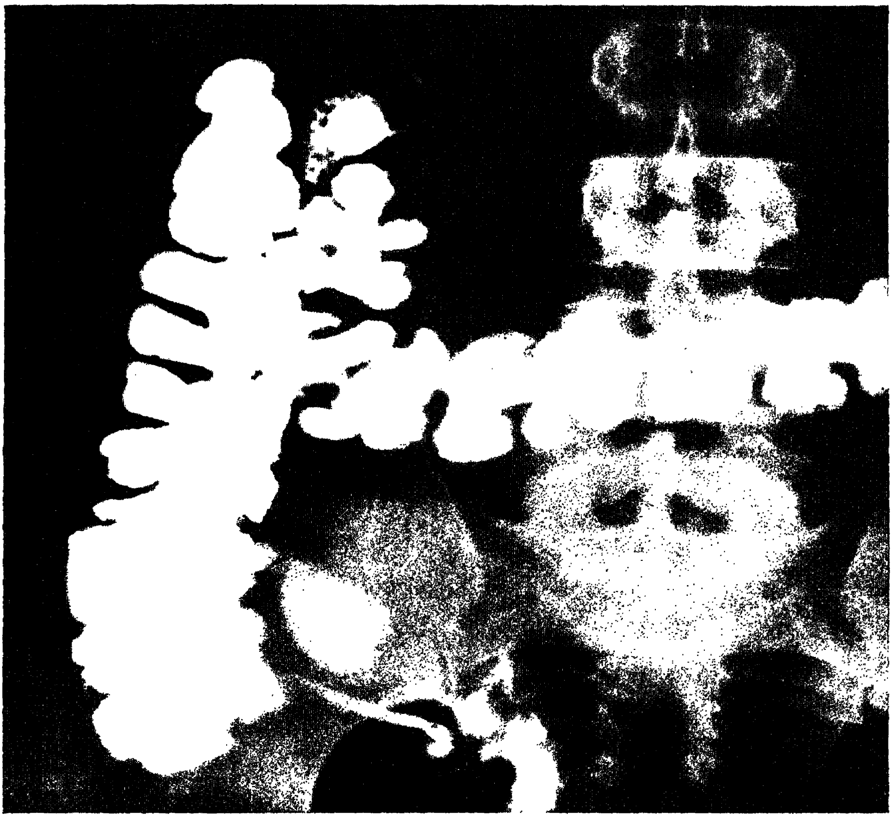
The *left colic flexure* (fig. 1178) is situated at the junction of the transverse and descending parts of the colon in the left hypochondriac region, and is in relation with the lateral end of the spleen and the tail of the pancreas, above, and with the anterior aspect of the left kidney, medially; the flexure is so acute that the end of the transverse colon usually lies in contact with the front of the descending colon. The left colic flexure lies at a higher level than, and on a plane posterior to, the right colic flexure (Pl. XVI, fig. 2), and is attached to the Diaphragm, opposite the tenth and eleventh ribs, by a peritoneal fold, named the *phrenicocolic ligament*, which lies in relation to the lateral end of the spleen (p. 1314).

The **descending colon** (fig. 1178), about 25 cm. long, passes downwards through the left hypochondriac and lumbar regions. At first it follows the lower part of the lateral border of the left kidney and then, at the lower pole of that organ, it descends, in the angle between Psoas major and Quadratus lumborum, to the crest of the ilium; it then curves downwards and medially in front of the Iliacus and Psoas major, and ends in the pelvic colon at the inlet of the true pelvis.† The peritoneum covers its anterior surface and sides, while its posterior surface is connected by areolar tissue with the lower and lateral part of the left kidney, the aponeurotic origin of the Transversus abdominis, the Quadratus lumborum, the Iliacus and the Psoas major (fig. 1191). Numerous structures cross behind it. They include :—the subcostal vessels and nerve, the iliohypogastric and ilio-inguinal nerves, the fourth lumbar artery (as a rule), the lateral femoral cutaneous, femoral and genitofemoral nerves, the testicular

* Treves examined one hundred subjects, and found that in fifty-two there was neither an ascending nor a descending mesocolon; in fourteen both were present; while in twelve there was an ascending, and in twenty-two a descending, mesocolon. It follows, therefore, that when lumbar colotomy is performed, a mesocolon may be expected upon the left side in 36 per cent. of all cases, and on the right in 26 per cent.—*The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885, p. 55.

† The descending colon is sometimes described as ending at the level of the iliac crest, the part between that level and the inlet of the true pelvis being named the *iliac colon*.

PLATE XVII



Radiograph of part of the large intestine after a barium meal.

Note the vermiform appendix, which passes from the medial side of the caecum medially and slightly downwards into the true pelvis. At a slightly higher level the terminal part of the ileum can be recognised. The first part of the transverse colon runs downwards in front of, and slightly medial to, the ascending colon, before it turns to the left.

PLATE XVIII

Radiograph of the genital tract in the female, after an injection of barium sulphate into the uterus.

X = body of uterus. Note the two cornua leading to the uterine tubes.

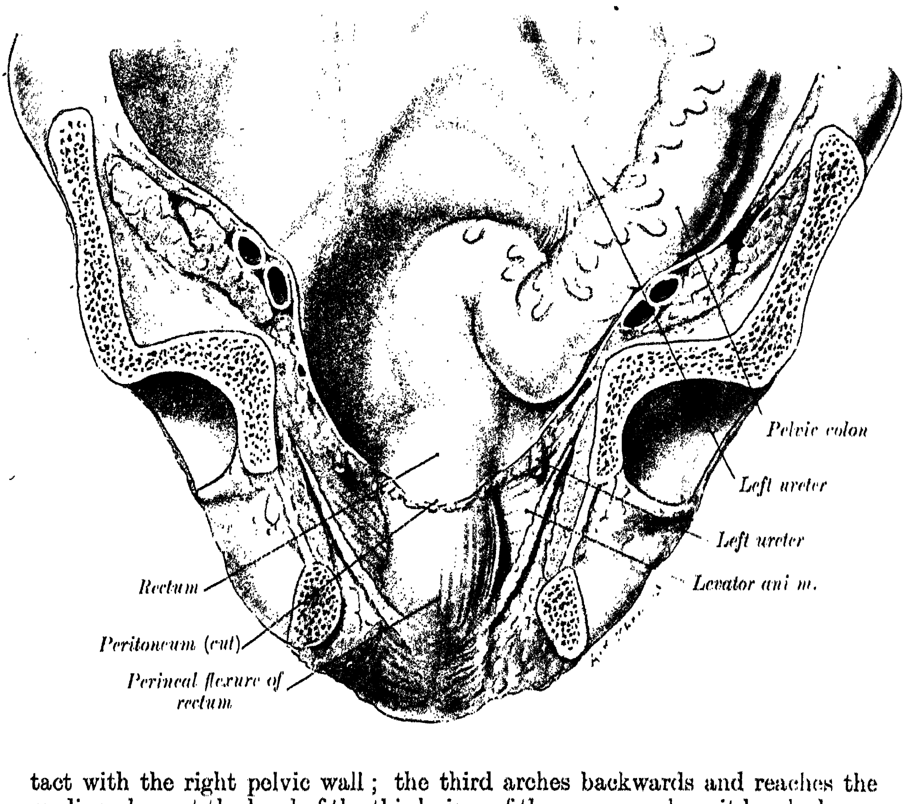
XX = speculum in vagina.

The arrows indicate the infundibula of the uterine tubes. Some of the barium has passed through the pelvic opening of the tube into the general peritoneal cavity.

(or ovarian) vessels and the external iliac artery, all of the left side. The descending colon is smaller in calibre, more deeply placed, and more frequently covered with peritoneum on its posterior surface, than the ascending colon (p. 1336 *). Anteriorly it is related to coils of the jejunum.

The **pelvic colon** (fig. 1191) begins at the inlet of the true pelvis, where it is continuous with the descending colon; it forms a loop which varies greatly in length, but averages about 40 cm., and normally lies within the pelvis. The loop consists of three parts; the first part descends in contact with the left pelvic wall; the second crosses the pelvic cavity, between the rectum and bladder in the male, and the rectum and uterus in the female, and may come into con-

FIG. 1191.—An oblique coronal section through the pelvis to expose the rectum from in front.

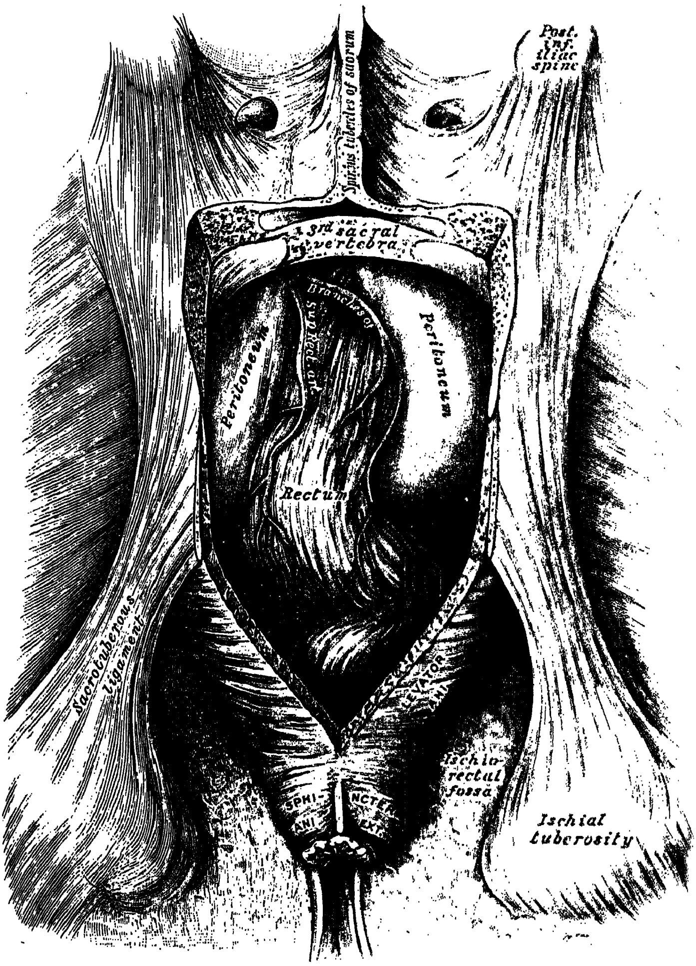


tact with the right pelvic wall; the third arches backwards and reaches the median plane at the level of the third piece of the sacrum, where it bends downward and ends in the rectum. The pelvic colon is completely surrounded by peritoneum, which forms a mesentery, termed the *pelvic mesocolon* (p. 1314); this diminishes in length from the centre towards the ends of the loop, where it disappears, so that the loop is fixed at its junctions with the descending colon and rectum, but enjoys a considerable range of movement in its central portion. Its relations are therefore subject to considerable variation. *Laterally* it is related to the external iliac vessels, the obturator nerve, the ovary (in the female), the vas deferens (in the male) and the lateral pelvic wall. *Posteriorly* it is related to the internal iliac (hypogastric) vessels, the ureter, the Piriformis and the sacral plexus, all of the left side. *Inferiorly* it rests on the bladder, in the male, and on the uterus and bladder, in the female. *Above* and on its *right side*, it is in contact with the terminal coil of the ileum.

The position and shape of the pelvic colon vary very much, and depend on (*a*) its length; (*b*) the length and freedom of its mesocolon; (*c*) the condition of distension; when distended it rises out of the pelvis into the abdominal cavity, and when empty it sinks again into the pelvis; (*d*) the condition of the rectum and bladder (and the uterus, in the female); when these organs are distended the pelvic colon tends to rise, and conversely.

The **rectum** (figs. 1191 to 1193) is continuous above with the pelvic colon, whilst below it ends in the anal canal. From its origin at the level of the third sacral vertebra it passes downwards, lying in the sacrococcygeal curve, and extends for 2 or 3 cm. in front of, and a little below, the tip of the coccyx, as far as the apex of the prostate. It then bends sharply backwards into the anal canal. It therefore presents two anteroposterior flexures: an upper or *sacral flexure* with its convexity backwards, and a lower or *perineal flexure* with its

FIG. 1192.—The rectum viewed from behind. Exposed by the removal of the lower part of the sacrum and the coccyx.



convexity forwards. Three lateral curves are also described, one convex to the right opposite the junction of the third and fourth sacral vertebræ, a second convex to the left, opposite the sacrococcygeal articulation, and a third, convex to the right, in front of the tip of the coccyx. As a result of these lateral curves the rectum is not exactly in the median plane, except at its upper and lower ends, the intermediate part bulging towards the left. The rectum is about 12 cm. long, and at its commencement its calibre is similar to that of the pelvic colon, but near its termination it is dilated to form the *rectal ampulla*. It has no sacculations comparable to those of the colon, but when the lower part of it is contracted its mucous membrane is thrown into a number of folds, which are longitudinal in direction and are effaced by the distension of the gut. Besides these there are certain permanent *horizontal folds* of a semilunar shape (fig. 1193). There are usually three of these horizontal folds, but sometimes four or five, and frequently only two, are present. One is situated near the commence-

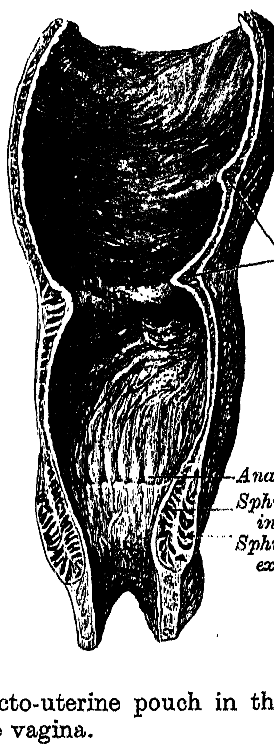
ment of the rectum, on the right side ; a second extends inwards from the left side of the tube at a slightly lower level ; a third, the largest and most constant, projects backwards from the fore part of the rectum, opposite the fundus of the urinary bladder. When a fourth is present, it is situated nearly 2·5 cm. above the anus, on the left and posterior wall of the tube. These folds are about 12 mm. in width and contain some of the circular fibres of the gut. In the empty state of the intestines they overlap each other so effectually that considerable manœuvring is required to conduct a bougie or the finger along the canal. Their use seems to be 'to support the weight of fæcal matter, and prevent its urging towards the anus, where its presence always excites a sensation demanding its discharge.' *

The peritoneum is related to the upper two-thirds of the rectum, covering at first its front and sides, but lower down its front only ; from the latter it is reflected on to the bladder in the male and the posterior vaginal wall in the female.

The level at which the peritoneum is reflected from the rectum to the viscus in front of it is higher in the male than in the female. In the former the height of the rectovesical pouch is about 7·5 cm. (i.e. the height to which an ordinary index finger can reach) from the anus. In the female the height of the recto-uterine pouch is about 5·5 cm. from the anal orifice. The lower part of the rectum is surrounded by a dense tube of fascia which consists of a localised thickening and compression of the extraperitoneal tissue ; this fascial tube is loosely attached to the rectal wall by areolar tissue, in order to allow of distension of the viscus.

Relations of the rectum.—The upper part of the rectum is in relation, *behind*, with the lower three sacral vertebræ, the coccyx and the anococcygeal raphe, in the median plane, but the median sacral vessels, the ganglion impar and, at its upper end, the superior rectal vessels intervene. On each side of the median plane, but especially on the left side, the rectum lies in front of the Piriformis muscle, the third, fourth and fifth sacral and the coccygeal nerves, the sympathetic trunk, the lower lateral sacral vessels, the Coccygeus and the Levator ani muscles ; it is attached to the sacrum along the lines of the sacral foramina by fibro-areolar tissue which surrounds the sacral nerves and the branches of the superior rectal vessels passing to the bowel. *In front*, the rectum is related, above, to the rectovesical pouch of the peritoneum, in the male, to the recto-uterine pouch in the female. These pouches contain the terminal coils of the ileum, and frequently the pelvic colon. Below the rectovesical pouch in the male the anterior surface of the rectum is in relation with a portion of the base of the bladder, the vesiculæ seminales and vasa deferentia. The rectal ampulla is related in front to the posterior surface of the prostate, a loose, cellular interval separating it from the recto-vesical fascia, which forms the posterior wall of the prostatic sheath ; below the recto-uterine pouch in the female, it is in relation with the posterior wall of the vagina.

FIG. 1193.—A coronal section through the rectum and anal canal.



* Paterson (*Journal of Anatomy and Physiology*, vol. xliii.) utilised the third fold for the purpose of dividing the rectum into an upper and a lower portion ; he considered the latter 'to be just as much a duct as the narrower anal canal below,' and maintained that, under normal conditions, it does not contain fæces except during the act of defæcation. Hurst (*Constipation*, Oxford University Press, 1919) believes that the pelvic colon acts as a reservoir and that, in normal individuals, the passage of fæces from the pelvic colon into the rectum is always followed by the desire to defæcate.

The **anal canal** (fig. 1193) begins at the level of the apex of the prostate, is directed downwards and backwards through the pelvic floor, and ends at the anus. It forms an angle with the lower part of the rectum, and is from 2 to 3 cm. long. It has no peritoneal covering, but is invested by the Sphincter ani internus, supported by the Levatores ani, and surrounded at its termination by the Sphincter ani externus. In the empty condition it presents the appearance of an anteroposterior longitudinal slit. Behind, it is in contact with a mass of muscular and fibrous tissue, termed the *anococcygeal body* (Symington); in front, it is separated by the *perineal body* from the membranous part of the urethra and the bulb of the penis in the male, and from the lower end of the vagina in the female.

The upper half of the anal canal is lined by mucous membrane which presents from six to ten vertical folds known as the *anal* (rectal) *columns*. These columns are usually well marked in the new-born child (fig. 1194), but are often ill-defined in the adult. They are produced by infoldings of the mucous membrane and of some of the longitudinal muscular tissue, and each contains a small artery and vein. They are separated from one another by furrows, and end below in small crescentic valve-like folds, termed *anal valves*; these valves join together the lower ends of the anal columns, and each forms the inner wall of a small pouch or *anal sinus*.

The lower half of the anal canal is lined with skin (p. 172) and exhibits a series of folds extending upwards from the anus towards the anal columns. The junction of the skin and mucous membrane is indicated by a white line, which is somewhat wavy 'owing to the interlocking of the cutaneous and mucous folds' (Symington).

The **anus** or **anal orifice** is the lower aperture of the anal canal, and is situated in front of the apex of the coccyx in the cleft between the buttocks. The skin surrounding it is thrown into a series of folds which converge towards the orifice and are continued upwards into the lower part of the anal canal.

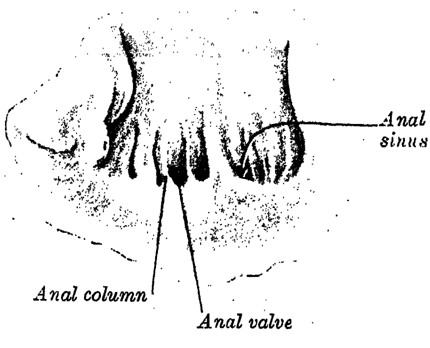
Structure of the large intestine.—The large intestine has four coats: serous, muscular, areolar and mucous.

The *serous coat* is derived from the peritoneum, and invests the different portions of the large intestine to a variable extent (*vide ante*). In the course of the colon the peritoneal coat is thrown into a number of small pouches filled with fat, called *appendices epiploicæ*. They are most numerous on the transverse colon.

The *muscular coat* consists of an external longitudinal, and an internal circular layer of non-striped muscular fibres.

The *longitudinal fibres* do not form a continuous layer over the whole surface of the large intestine. In the cæcum and colon they are collected into three longitudinal bands (*tæniæ coli*), each of about 12 mm. in width; one (the *tænia mesocolica*) is placed along the attached border of the intestine; the second and largest (the *tænia omentalis*) corresponds, along the curve of the transverse colon, with the attachment of the greater omentum, but is placed anteriorly in the ascending, descending and pelvic parts of the colon; the third (the *tænia libera*) is found on the medial sides of the ascending and descending parts of the colon, and on the under surface of the transverse colon. These bands are shorter than the other coats of the intestine, and serve to produce the sacculi which are characteristic of the cæcum and colon; accordingly, when they are dissected off, the tube can be lengthened, and its sacculated character becomes lost. In the pelvic colon the longitudinal fibres become more scattered; and round the rectum they spread out and form a layer, which completely encircles this portion of the gut, but is thicker on the anterior and posterior surfaces, so that an anterior and a posterior band can be recognised. At the rectal ampulla, a few strands of the anterior longitudinal fibres pass forwards to the perineal body (fig. 608); they constitute the *recto-urethralis muscle*. In addition, two fasciculi of plain muscular tissue arise from the front of the second and third coccygeal vertebræ, and pass downwards and forwards to blend with the lon-

FIG. 1194.—The interior of the anal canal of a new-born child.



gitudinal muscular fibres on the posterior wall of the anal canal. These are known as the *Rectococcygeal muscles.* A thin stratum of involuntary muscular fibres radiates from the anal orifice and is named the *Corrugator cutis ani.* Centrally the fibres fade off into the subcutaneous tissue ; externally they blend with the true skin.

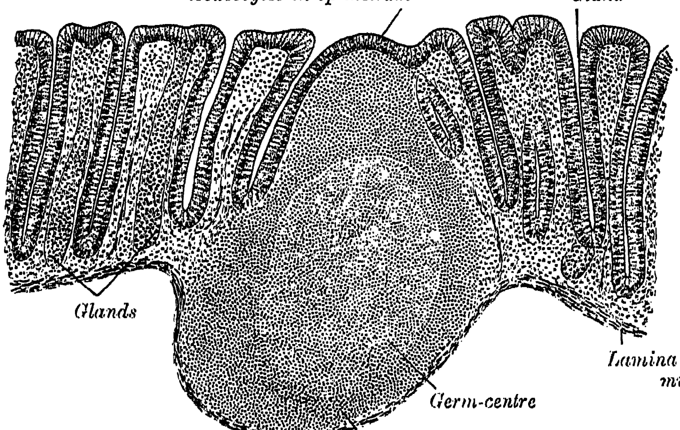
The *circular fibres* form a thin layer over the cæcum and colon, being especially accumulated in the intervals between the sacculi ; in the rectum they form a thick layer, and in the anal canal they become numerous, and constitute the Sphincter ani internus.

The Sphincter ani internus is a muscular ring which surrounds the upper 2·5 cm. of the anal canal ; below, it is in contact with the Sphincter ani externus and, posteriorly and on each side, it is covered by the Puborectalis. It assists the Sphincter ani externus and the Puborectalis to occlude the anal canal.

The *areolar coat* connects the muscular and mucous layers closely together.

The *mucous membrane* of the cæcum and colon is pale, smooth, destitute of villi, and raised into numerous crescentic folds which correspond with the intervals between the sacculi ; that of the rectum is thicker, of a darker colour, more vascular and connected loosely with the muscular coat.

FIG. 1195.—A section through the mucous membrane of the human rectum. × 60. (Sobotta.)



As in the small intestine, the mucous membrane consists of a muscular layer [lamina muscularis mucosæ] ; a quantity of retiform tissue in which the vessels ramify ; a basement-membrane, and an epithelium which is of the columnar variety and resembles the epithelium found in the small intestine. The mucous membrane of the large intestine presents for examination glands and solitary lymphatic nodules.

The *glands* of the large intestine are minute tubular prolongations of the mucous membrane arranged perpendicularly to its surface ; they are longer, more numerous, and placed in much closer apposition than those of the small intestine ; and they open by minute rounded orifices upon the surface, giving it a cribriform appearance. Each gland is lined with short columnar epithelium, the majority of the cells being goblet-cells.

The *solitary lymphatic nodules* (fig. 1195) of the large intestine are most abundant in the cæcum and vermiform appendix, but are irregularly scattered over the rest of the large intestine also. They are similar to those of the small intestine.

The structure of the vermiform appendix is described on p. 1335.

Vessels and Nerves —The *arteries* supplying the colon are derived from the colic branches of the mesenteric arteries. They give off large branches, which ramify between and supply the muscular coats, and after dividing into small vessels in the submucous tissue pass to the mucous membrane. The rectum is supplied by the superior rectal (hæmorrhoidal) branch of the inferior mesenteric, and the anal canal by the middle rectal from the internal iliac (hypogastric), and the inferior rectal from the internal pudendal artery. The superior rectal (the continuation of the inferior mesenteric) divides into two branches, which run down one on each side of the rectum ; they divide into a number of branches, which pierce the muscular coat and descend between it and the mucous membrane in the anal columns as far as the Sphincter ani internus, where they anastomose with the other rectal arteries and form a series of loops around the anus. The *veins* of the rectum commence in a plexus of vessels which surrounds the anal canal. In the vessels forming this plexus small saccular dilatations occur just within the margin of the anus ; from the plexus about six vessels of considerable size are given off. These ascend between the muscular and mucous coats,

running parallel to one another; at about the middle of the rectum they pierce the muscular coat, and, by their union, form a single trunk [the superior rectal vein]. This arrangement is termed the *rectal* (*hæmorrhoidal*) *plexus*; it communicates with the tributaries of the middle and inferior rectal veins, at its commencement, and thus a communication is established between the systemic and portal circulations. The *nerves* are derived from the second, third and fourth sacral nerves (parasympathetic), and from the sympathetic, through the pelvic plexuses. They are distributed in a similar way to those found in the small intestine.

The *lymph glands and vessels* of the large intestine are described on pp. 868, 870.

Applied Anatomy.—The small intestine is much exposed to injury, but, in consequence of its elasticity and the ease with which one coil glides over another, it is not so frequently ruptured as would otherwise be the case. Any part of it may be ruptured, but probably the most common situation is the third part of the duodenum, because it is more fixed than other portions of the bowel, and because it is situated in front of the vertebral column, so that if this portion of the intestine is struck by a sharp blow, such as the kick of a horse, it is unable to glide out of the way, but is compressed against the bone and so lacerated. The small intestine, and most frequently the ileum, may become strangulated by internal bands, or through apertures, normal or abnormal. Intussusception, most commonly an invagination of the small intestine into the large, may take place; it may attain great size, and it is possible in these cases to find the ileocolic valve projecting from the anus. Stricture, the impaction of foreign bodies, and twisting of the gut (*volvulus*) may also lead to intestinal obstruction.

The vermiform appendix is very liable to become inflamed, because it contains a relatively large amount of lymphoid tissue, which is prone to bacterial infection. In many cases the inflammation is set up by the impaction in it of a solid mass of fæces or a foreign body, or by the inspissation of its mucous secretion in catarrhal conditions. The inflammation may result in ulceration and perforation, or if very acute in gangrene of the organ. These conditions generally require immediate operative interference.

In external hernia the ileum is the portion of bowel most frequently herniated. When a part of the large intestine is involved it is usually the cæcum or the pelvic colon. In some few cases the vermiform appendix has been the part implicated in strangulated hernia.

The calibre of the large intestine gradually diminishes from the cæcum, which has the greatest diameter of any part of the bowel, to the point of junction of the pelvic colon with the rectum. At or a little below this point stricture most commonly occurs, and diminishes in frequency as one proceeds upwards to the cæcum. When distended by some obstruction low down, the outline of the large intestine can be defined throughout nearly the whole of its course—all, in fact, except the right and left colic flexures, which are more deeply placed; the distension is most obvious in the flanks and on the front of the abdomen just above the umbilicus. The cæcum, however, is the portion of the bowel which becomes most distended. It may assume enormous dimensions, and may rupture from the distension, leading to rapidly fatal peritonitis. The mobility of the pelvic colon renders it more liable to become the seat of a volvulus or twist than any other part of the intestine. This generally occurs in patients who have been the subjects of habitual constipation, and in whom, therefore, the mesocolon is elongated.

Hernia.—The two chief sites at which external hernia may take place are the inguinal region and the femoral canal. The description of the inguinal canal and its relations will be found on p. 571 and that of the femoral canal on p. 785. The peritoneal areas concerned are described on p. 1309.

In the usual position of the parts, the floor of the lateral inguinal fossa corresponds to the deep (abdominal) inguinal ring, and into this fossa an oblique inguinal hernia descends. On the medial side of the epigastric fold are the medial inguinal and the supravesical fossæ, and through either of these a direct hernia may descend. The whole of the space between the inferior epigastric artery, the margin of the Rectus abdominis, and the inguinal ligament, is known as the inguinal triangle.

Inguinal hernia.—Inguinal hernia is that form of protrusion which makes its way through the abdominal wall in the inguinal region. There are two principal varieties: lateral or oblique, and medial or direct.

In *oblique inguinal hernia* the intestine escapes from the abdominal cavity at the deep inguinal ring, pushing before it a pouch of peritoneum which forms the hernial sac. As it enters the inguinal canal it receives an investment from the extraperitoneal tissue and passes into the internal spermatic fascia which encloses the constituents of the spermatic cord. In passing along the inguinal canal it displaces upwards the arched fibres of the Transversus and Obliquus internus, and receives a covering of Cremaster muscle and cremasteric fascia. It lies in front of the constituents of the spermatic cord and escapes from the inguinal canal at the superficial inguinal ring, becoming invested by the external spermatic fascia. Lastly it descends into the scrotum, receiving coverings from the superficial fascia and the skin.

The site of strangulation in oblique inguinal hernia is either the deep or the superficial inguinal ring; most frequently at the former situation. If it is situated at the superficial

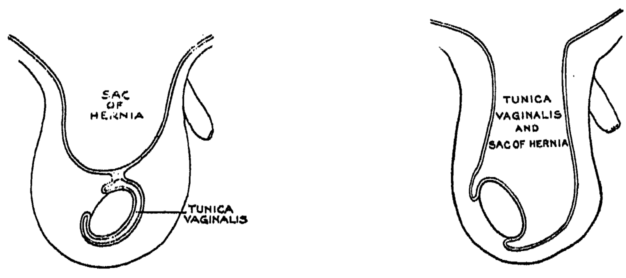
ring, the division of a few fibres at one point of the circumference is all that is necessary for the replacement of the hernia. If at the deep ring, it is necessary to divide the aponeurosis of the Obliquus externus so as to lay open the inguinal canal; in dividing the aponeurosis the incision should be directed parallel to the inguinal ligament, and the constriction at the deep ring should then be divided in an upward direction.

The great majority of varieties of oblique inguinal hernia depend upon congenital defects in the processus vaginalis, the pouch of peritoneum which precedes the descent of the testis. Normally this pouch is closed before birth, closure commencing at two points, viz. at the deep inguinal ring and at the top of the epididymis, and gradually extending until the whole of the intervening portion is converted into a fibrous cord. From failure in the completion of this process, variations in the relation of the hernial protrusion to the testis and tunica vaginalis are produced; these constitute distinct varieties of inguinal hernia, viz. the hernia of the funicular process and the complete congenital variety.

Where the processus vaginalis remains patent throughout, the cavity of the tunica vaginalis communicates directly with that of the peritoneum. The intestine descends along this pouch into the cavity of the tunica vaginalis, which constitutes the sac of the hernia, and the gut lies in contact with the testis. Though this form of hernia is termed *complete* congenital (fig. 1196), the term does not imply that the hernia existed at birth, but merely that a condition is present which may allow of the descent of the hernia at any moment. As a matter of fact, congenital herniæ frequently do not appear till adult life.

Where the processus vaginalis is occluded at the lower point only, i.e. just above the testis, the intestine descends into the pouch of peritoneum as far as the testis, but is pre-

FIG. 1196.—The varieties of oblique inguinal hernia.



Incomplete congenital   Complete congenital

vented from entering the sac of the tunica vaginalis by the septum which has formed between it and the pouch. This is known as *hernia into the funicular process* or *incomplete congenital* hernia (fig. 1196); it differs from the former in that instead of enveloping the testis it lies above it.

In *direct inguinal hernia* the protrusion makes its way through some part of the inguinal triangle, either through (*a*) the lateral part, where only extraperitoneal tissue and transversalis fascia intervene between the peritoneum and the aponeurosis of the Obliquus externus; or through (*b*) the conjoint tendon, which stretches across the medial two-thirds of the triangle between the artery and the median plane. In the former the hernial protrusion escapes from the abdomen on the lateral side of the conjoint tendon, pushes before it the peritoneum, extraperitoneal tissue and transversalis fascia, and enters the inguinal canal. It passes along nearly the whole length of the canal and finally emerges from the superficial ring, receiving an investment from the external spermatic fascia. The coverings of this form of hernia are similar to those of the oblique form, except that a portion derived from the general layer of transversalis fascia replaces the internal spermatic fascia so that the hernia lies between the innermost and the middle covering of the spermatic cord.

In the second form, which is the more frequent, the hernia is either forced through the fibres of the conjoint tendon, or the tendon is gradually distended in front of it so as to form a complete investment for it. The intestine then enters the lower end of the inguinal canal, escapes at the superficial ring, lying on the medial side of the cord, and receives additional coverings from the external spermatic fascia, the superficial fascia and the skin. The coverings of this form therefore differ from those of the oblique form in that the conjoint tendon is substituted for the Cremaster, and the internal spermatic fascia is replaced by a portion of the general layer of the transversalis fascia. It may be observed that in all the varieties of inguinal hernia the most superficial covering is an investment from the external spermatic fascia and is identical with the outermost covering of the spermatic cord. An oblique inguinal hernia lies within the spermatic cord and shares all its coverings, but the covering which a direct hernia acquires from the transversalis fascia is distinct from the covering which the spermatic cord receives from that layer.

Direct inguinal hernia is of much less frequent occurrence than oblique, and is found more often in men than in women. The main differences in position between it and the oblique form are: (*a*) it is placed over the os pubis and not in the course of the inguinal canal; (*b*) the inferior epigastric artery runs on the lateral or iliac side of the neck of the sac; and (*c*) the spermatic cord lies along its lateral and posterior sides, not directly behind it as in oblique inguinal hernia. A direct hernia is always of the acquired variety.

The seat of stricture in both varieties of direct hernia is usually found either at the neck of the sac or at the superficial ring. In that form which perforates the conjoint tendon it may occur at the edges of the fissure through which the gut passes. In all cases of inguinal hernia, whether direct or oblique, it is proper to divide the stricture directly upwards; by cutting in this direction the incision is made parallel to the inferior epigastric artery, and all chance of wounding the vessel is thus avoided.

Femoral hernia.—In femoral hernia the protrusion of the intestine takes place through the femoral ring. As already described (p. 785), this ring is closed by the femoral septum, a partition of modified extraperitoneal tissue; it is therefore a weak spot in the abdominal wall, and especially in the female, where the ring is larger, and where profound changes are produced in the tissues of the abdomen by pregnancy. Femoral hernia is therefore more common in women than in men.

When a portion of the intestine is forced through the femoral ring, it carries before it a pouch of peritoneum which forms the hernial sac. It receives an investment from the extraperitoneal tissue or femoral septum, and descends along the femoral canal as far as the saphenous opening (fossa ovalis); at this point it changes its course, being prevented from extending farther down the sheath on account of the narrowing of the latter, and its close contact with the vessels, and also the close attachment of the superficial fascia and femoral sheath to the lower part of the circumference of the saphenous opening. The tumour is consequently directed forwards, pushing before it the cribriform fascia, and then curves upwards over the inguinal ligament and the lower part of the aponeurosis of the Obliquus externus, being covered by the superficial fascia and skin. While the hernia is contained in the femoral canal it is usually of small size, owing to the resisting nature of the surrounding parts, but when it escapes from the saphenous opening into the loose areolar tissue of the groin it becomes considerably enlarged. The direction taken by a femoral hernia is at first downwards, then forwards and upwards; in the application of taxis for the reduction of a femoral hernia, therefore, pressure should be directed in the reverse order, and the thighs should be passively flexed in order that the greatest degree of relaxation may be obtained.

The coverings of a femoral hernia from within outwards are: peritoneum, femoral septum, femoral sheath, cribriform fascia, superficial fascia and skin. Sir Astley Cooper described an investment for femoral hernia under the name of *fascia propria*, lying immediately external to the peritoneal sac but frequently separated from it by some adipose tissue. Surgically it is important to remember the frequent existence of this layer on account of the ease with which an inexperienced operator may mistake the fascia for the peritoneal sac and the contained extraperitoneal fat for omentum, as there is often a great excess of subperitoneal fatty tissue enclosed in the 'fascia propria.' In many cases it resembles a fatty tumour, but on further dissection the true hernial sac will be found in the centre of the mass of fat. The fascia propria is merely a modified femoral septum which had been thickened to form a membranous sheet by the pressure of the hernia.

When the intestine descends along the femoral canal only as far as the saphenous opening the condition is known as *incomplete* femoral hernia, in contradistinction to the *complete* hernia, which has passed through the opening. The small size of the protrusion in the incomplete form of hernia, on account of the firm and resisting nature of the canal in which it is contained, renders it an exceedingly dangerous variety of the disease, from the extreme difficulty of detecting the existence of the swelling, especially in corpulent subjects.

The site of strangulation of a femoral hernia varies: it may be at the neck of the hernial sac; in the greater number of cases it is at the point of junction of the falciform margin of the saphenous opening with the free edge of the pectineal part of the inguinal ligament (lacunar ligament); or it may be at the margin of the saphenous opening. The stricture should in every case be divided in a direction upwards and medially for a distance of about 4 mm. to 6 mm. All vessels or other structures of importance in relation to the neck of the sac will thus be avoided.

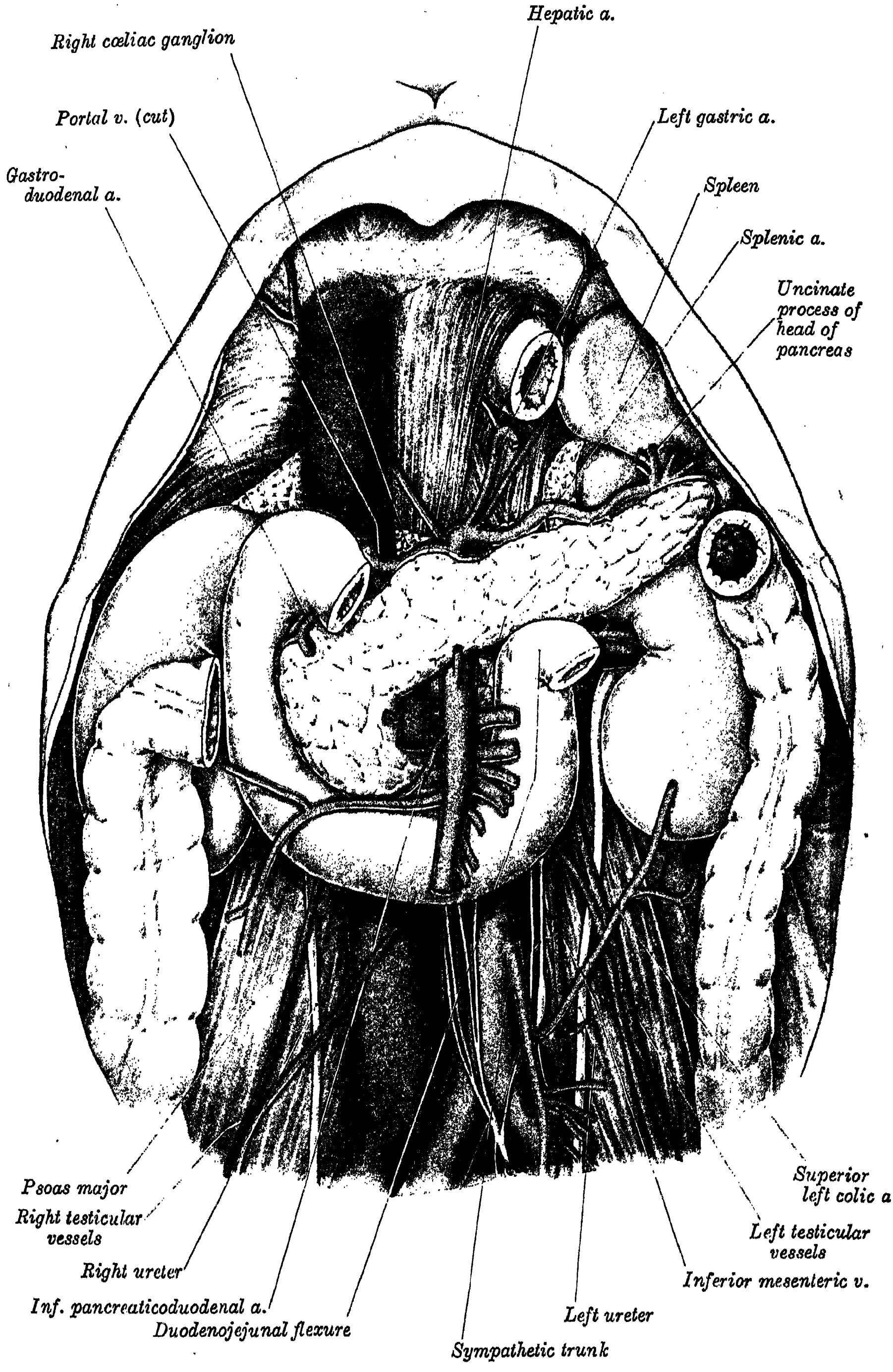
The pubic tubercle forms an important landmark in serving to differentiate the inguinal from the femoral variety of hernia. The neck of the inguinal protrusion is above and medial to the tubercle, while the neck of the femoral protrusion is below and lateral to it.

The Pancreas

The pancreas is a compound racemose gland, analogous in its structure to the salivary glands, but softer, and less compactly arranged. It is flattened and elongated, measuring from 12 cm. to 15 cm. long. Its broad, right extremity

is called the *head*, and is connected to the main portion, or *body*, by a slightly constricted *neck*; its narrow, left extremity forms the *tail*. It passes obliquely

FIG. 1197.—The pancreas and duodenum. Anterior aspect.



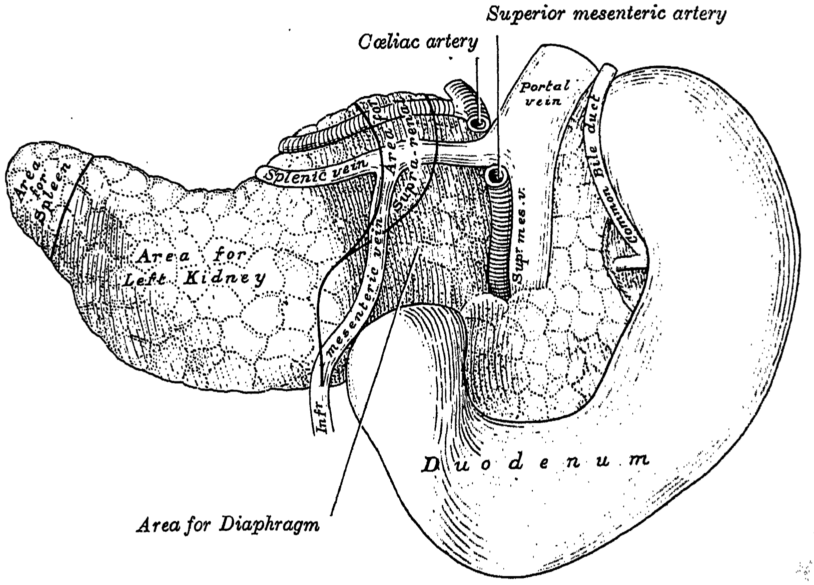
upwards and to the left, across the posterior wall of the abdomen, at the back of the epigastric and left hypochondriac regions.

Relations (figs. 1197 to 1199).—The **head**, flattened from before backwards,

is lodged within the curve of the duodenum. Its upper border is overlapped by the first part of the duodenum; the other borders are grooved to receive the adjacent margin of the duodenum, which they overlap in front and behind to a variable extent. At the angle of junction of the lower with the left lateral border there is a prolongation named the *uncinate process*, which projects upwards and to the left behind the superior mesenteric vessels. In or near the groove between the duodenum and the right lateral and lower borders anteriorly are the anastomosing superior and inferior pancreaticoduodenal arteries.

Anterior surface.—From the upper part of the front of the head of the pancreas, the neck juts forwards, upwards and towards the left, to be continued into the body of the pancreas. The boundary between the head and neck, on the right side, is a groove for the gastroduodenal artery; on the left side a deep notch intervenes between the head and the neck, and in it the superior mesenteric and splenic veins unite to form the portal vein. Below and to the right of

FIG. 1198.—The pancreas and duodenum. Posterior surface. (From a model by His.)



the neck the anterior surface of the head is in contact with the transverse colon, only areolar tissue intervening, while still lower the surface is covered with peritoneum continuous with the inferior layer of the transverse mesocolon (fig. 1161), and is in contact with a coil of the jejunum. The uncinate process is crossed by the superior mesenteric vessels.

Posterior surface.—The posterior surface of the head of the pancreas is in relation with the inferior vena cava, which runs upwards behind it and covers nearly the whole of this aspect. In addition, it is related to the terminal parts of the renal veins and the right crus of the Diaphragm. The uncinate process passes in front of the aorta. The bile duct lies either in a groove on the upper and lateral part of the posterior surface of the head of the pancreas or in a canal in its substance (McConnell *).

The **neck**, about 2 cm. long, is confluent below and to the right with the anterior surface of the head; it extends upwards and to the left, and merges imperceptibly into the body. Its anterior surface is covered with peritoneum and supports the pylorus, a portion of the lesser sac of the peritoneum (omental bursa) intervening; the gastroduodenal and the superior pancreaticoduodenal arteries descend in front of the gland at the right side of the junction of the neck with the head; its posterior surface is in relation with the superior mesenteric vein and the beginning of the portal vein.

* *Journal of Anatomy and Physiology*, vol. xlix.

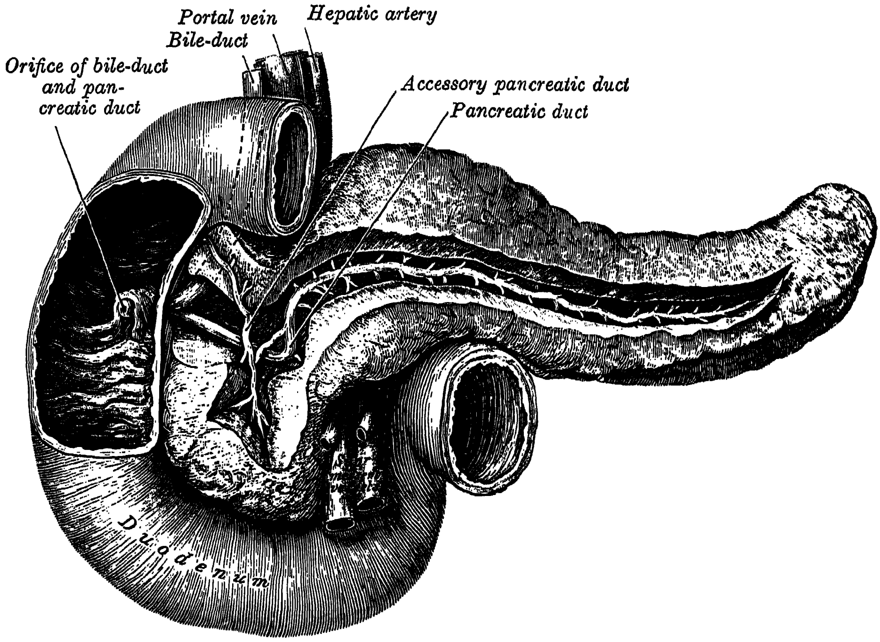
The **body** is somewhat prismoid in shape, and has three surfaces: anterior, posterior and inferior.

The *anterior surface* is concave, and is directed forwards and upwards; it is covered with peritoneum and is separated from the stomach by the lesser sac.

The *posterior surface* is devoid of peritoneum, and is in contact with the aorta and the origin of the superior mesenteric artery, the left crus of the Diaphragm, the left suprarenal gland and the left kidney and its vessels. It is intimately related to the splenic vein, which courses from left to right and separates it from the structures mentioned.

The *inferior surface* is narrow on the right but broader on the left, and is covered with peritoneum; it lies upon the duodenojejunal flexure and on some coils of the jejunum; its left extremity rests on the left colic flexure.

FIG. 1199.—The pancreatic duct.



The *superior border* is blunt and flat to the right; narrow and sharp to the left, near the tail. A process, termed the *tuber omentale*, usually projects from the right end of the superior border above the level of the lesser curvature of the stomach, and is in contact with the posterior surface of the lesser omentum. It is in relation above with the cœliac artery, from which the hepatic artery courses to the right just above the gland, while the splenic artery runs towards the left following a wavy course along this border.

The *anterior border* separates the anterior from the inferior surface, and along this border the two layers of the transverse mesocolon diverge from each other: one passing upwards over the anterior surface, the other backwards over the inferior surface.

The *inferior border* separates the posterior from the inferior surface: the superior mesenteric vessels emerge under its right extremity.

The **tail** is narrow, and usually lies in contact with the inferior part of the gastric surface of the spleen. It is contained within the two layers of the lienorenal ligament and is closely related to the splenic vessels.

The pancreatic duct traverses the pancreas from left to right, lying nearer its posterior than its anterior surface (fig. 1199). It begins by the junction of the small ducts of the lobules situated in the tail of the pancreas, and, running from left to right through the body, receives the ducts of the various lobules composing the gland. Considerably augmented in size, it reaches the neck of

the pancreas, and turning downwards, backwards, and to the right, comes into relation with the bile duct, which lies to its right side. Together the two ducts pass obliquely into the wall of the second part of the duodenum, and there unite to form a short dilated duct, named the *ampulla of the bile duct*. The constricted distal end of this ampulla opens on the summit of the duodenal papilla, which is situated within this part of the duodenum at the junction of its medial and posterior walls, from 8 cm. to 10 cm. distal to the pylorus. The pancreatic duct, near the duodenum, is about the size of an ordinary quill. Sometimes the pancreatic duct and the bile-duct open separately into the duodenum. Frequently there is an additional duct, which receives the ducts from the lower part of the head, and is known as the *accessory pancreatic duct* (fig. 1199). It runs upwards in front of the pancreatic duct, to which it is connected by a communicating duct, and opens into the duodenum about 2 cm. above and slightly ventral to the duodenal papilla.

Structure (fig. 1200).—In structure, the pancreas resembles the salivary glands. It differs from them, however, in certain particulars, and is looser and softer in its texture.

Fig. 1200.—A section through a part of the human pancreas. Stained with hæmatoxylin and eosin. ×400.

It is not enclosed in a distinct capsule, but is surrounded by areolar tissue, which dips into its interior, and connects together the various lobules of which it is composed. Each lobule, like the lobules of the salivary glands, consists of one of the ultimate ramifications of the main duct, ending in a number of alveoli, which are tubular and somewhat convoluted. The minute ducts (intercalary ducts) connected with the alveoli are narrow and lined with flattened cells. In some animals spindle-shaped cells occupy the centre of the alveolus and are known as *centro-acinar cells*. The true secreting cells, which line the wall of the alveolus, are columnar in shape and present two zones; an outer, clear and faintly striated, next the basement-membrane, and an inner, which contains secretory granules. In hardened specimens the outer zone stains deeply with basic dyes, whereas the inner zone stains slightly. During activity the granular zone gradually diminishes in size; during the resting stages it gradually increases until it forms nearly three-fourths of the cell. In some of the secreting cells of the pancreas there is a spherical mass, staining more easily than the rest of the cell; this is termed the *paranucleus*, and is believed to be derived from the nucleus. Between the alveoli collections of cells are found in certain parts, which are termed *interalveolar cell-islets*, or islands of Langerhans. The cells of these stain lightly with hæmatoxylin or carmine, and are more or less polyhedral in shape, forming a network in which many capillaries ramify. There are two main types of cell in the islets, distinguished as A-cells and B-cells according to the special staining reactions of the granules they contain. The cell-islets are believed to produce insulin, the internal secretion of the pancreas which is necessary for carbohydrate metabolism.

The wall of the pancreatic duct is thin, consisting of two coats, an external fibrous and an internal mucous; the latter is smooth, lined with columnar epithelium, and furnished near its termination with a few scattered follicles.

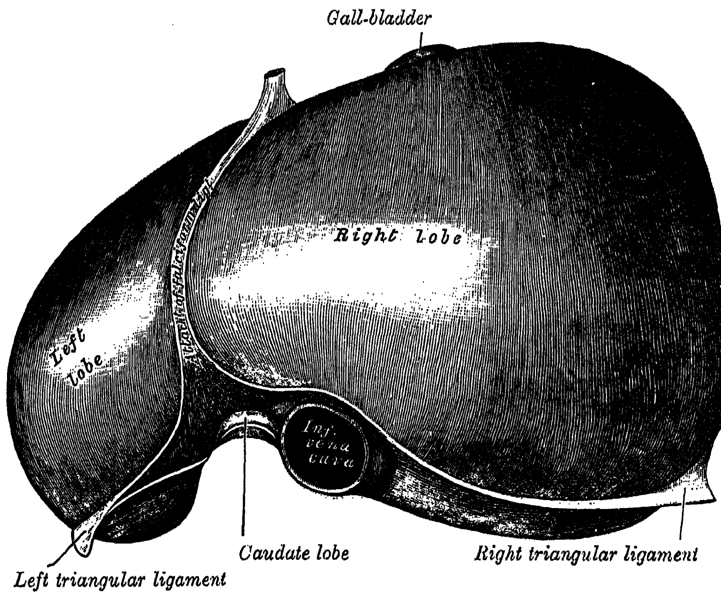
Vessels and Nerves.—The *arteries of the pancreas* are derived from the splenic artery, and from the pancreaticoduodenal branches of the hepatic and superior mesenteric arteries. Its *veins* open into the portal, splenic and superior mesenteric veins. Its *lymph vessels* are described on p. 868. Its *nerves*, derived from the vagus and splanchnic nerves, reach it through the splenic plexus.

Applied Anatomy.—Cysts of the pancreas may attain a large size, and cause symptoms by pressing on the stomach, Diaphragm or bile-duct. They generally push their way forwards between the stomach and transverse colon, and may then be felt in the upper part of the abdomen as a definite tumour in the median plane. The tumour is fixed and does not move with respiration. The pancreas is often the seat of cancer; this usually affects the head, and therefore speedily involves the bile-duct, leading to persistent jaundice; or it may press upon the portal vein, causing ascites, or involve the stomach, causing pyloric obstruction. The second part of the duodenum is occasionally encircled by the head of the pancreas, and should the latter then be the seat of malignant disease or chronic inflammation it may cause obstruction of the duodenum.

The Liver (Hepar) (figs. 1201 to 1203)

The liver, the largest gland in the body, is situated in the upper and right parts of the abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium, and not uncommonly extending into the left hypochondrium as far as the mammary line. In the male it weighs

Fig. 1201.—The superior, anterior, and right lateral surfaces of the liver. (From a model by His.)



from 1·4 to 1·6 kilogm., in the female from 1·2 to 1·4 kilogm. It is relatively much larger in the fœtus than in the adult, constituting, in the former, about one-eighteenth, and in the latter, about one-thirty-sixth of the entire body weight. Its greatest transverse measurement is from 15 cm. to 20 cm. Vertically, near its right surface, it measures from 15 cm. to 17 cm., while its greatest anteroposterior diameter is on a level with the upper end of the right kidney, and is from 12 cm. to 15 cm.; opposite the vertebral column this diameter is reduced to about 7 cm. Its consistence is that of a soft solid; it is, however, friable and easily lacerated; its colour is a dark reddish-brown.

When the liver has been hardened *in situ* it presents the appearance of a

wedge, the base of which is directed to the right and the edge to the left. Symington describes its shape as that 'of a right-angled triangular prism with the right angles rounded off.'

The liver possesses five surfaces, which will be described later, viz. superior, inferior, anterior, posterior, and right.

Borders.—The superior, anterior, and right surfaces are united by rounded borders, but a sharp margin, termed the *inferior border*, separates the right lateral and anterior surfaces from the inferior or visceral surface. Somewhat rounded where it intervenes between the right lateral and inferior surfaces, it is thin and sharp where it forms the lower margin of the anterior surface and is marked by a notch, termed the *notch of the ligamentum teres*, in or near the median plane. Lateral to the fundus of the gall bladder, which often corresponds to a second notch placed 4 to 5 cm. to the right of the median plane, this border generally corresponds with the costal margin. To the left of the fundus of the gall-bladder, it ascends less obliquely than the right costal margin and, crossing the infrasternal angle, passes behind the left costal margin in the neighbourhood of the tip of the eighth costal cartilage. Thereafter it ascends sharply and merges with the thin left margin of the left lobe. As it crosses the infrasternal angle the inferior border is closely related to the deep surface of the anterior abdominal wall and is readily accessible to examination by palpation or percussion. It should be noted that in women and children this border usually lies at a slightly lower level, i.e. it tends to project downwards for a short distance below the right costal margin.

Lobes.—The liver is divided, very imperfectly, into a large right and a much smaller left lobe. On the anterior and superior surfaces the two lobes meet along the line of attachment of a sickle-shaped fold of peritoneum which passes to the liver from the anterior abdominal wall and the under surface of the Diaphragm and is termed the falciform ligament (p. 1351). On the posterior and inferior surfaces the separation is more obvious and is effected by two fissures which meet end to end at the left extremity of the porta hepatis ; they are termed the fissure for the ligamentum venosum and the fissure for the ligamentum teres. The *fissure for the ligamentum venosum* is a deep cleft, lined with peritoneum, which descends on the posterior surface, nearer to its left than to its right limit. The *fissure for the ligamentum teres*, which is usually shallow, runs upwards and backwards on the inferior surface and extends from the inferior border of the liver to the left extremity of the porta hepatis.

The *left lobe* is thin, flattened from above downwards and only about one-sixth of the size of the whole organ. It presents anterior, superior, posterior and inferior surfaces, which are described with the surfaces of the liver (p. 1352).

The *right lobe*, which is somewhat cuboidal in form, constitutes the remaining five-sixths of the organ. It contributes to all of the surfaces of the liver, with which its surfaces will be described (p. 1352). The portion of the right lobe which adjoins the left lobe on the inferior and posterior surfaces is further subdivided into two smaller lobes, termed the quadrate and caudate lobes.

The *quadrate lobe* is placed on the inferior surface, and is somewhat rectangular in outline. It is bounded in front by the inferior border of the liver : on the left by the fissure for the ligamentum teres : behind by the porta hepatis : and on the right by a shallow fossa which lodges the gall-bladder.

The *caudate lobe* is situated on the posterior surface. It is bounded on the left by the fissure for the ligamentum venosum : below by the porta hepatis : and on the right by the deep groove which lodges the upper portion of the inferior vena cava. Above, it is continuous with the superior surface to the right of the upper end of the fissure for the ligamentum venosum. Below and to the right the caudate lobe is connected to the rest of the right lobe by a narrow tongue of liver substance, termed the *caudate process*, which lies immediately behind the porta hepatis and forms the roof of the aditus to the lesser sac (epiploic foramen). Below and to the left the caudate lobe presents a small rounded projection, which is termed the *papillary process*. In addition, owing to the depth of the fissure for the ligamentum venosum, the caudate lobe possesses a peritoneal-covered anterior surface, which forms the posterior wall of the fissure and is in contact with the hepatic part of the lesser omentum.

The relations of the quadrate and caudate lobes will be described with the surfaces of the liver (p. 1353).

Peritoneal connexions of the liver.—With the exception of an extensive, triangular area on the posterior surface of the right lobe, the liver is almost completely invested with peritoneum. It is connected to the stomach and duodenum, to the diaphragm and to the anterior abdominal wall by a number of peritoneal folds, and the lines along which they meet the organ are also necessarily devoid of a peritoneal covering. These folds include the falciform ligament, the right and left triangular ligaments, the coronary ligament and the lesser omentum.

The *falciform ligament* is a sickle-shaped fold consisting of two closely applied layers of peritoneum which connects the liver to the Diaphragm and the anterior abdominal wall. Its convex margin is fixed to the inferior surface of the Diaphragm and to the posterior surface of the anterior abdominal wall, extending downwards to the umbilicus ; as this attachment ascends from the umbilicus it passes slightly to the right of the median plane. The concave margin of the falciform ligament is attached to the notch for the ligamentum teres on the inferior border of the liver and to its anterior and superior surfaces. Its base or free edge, which extends from the umbilicus to the notch for the ligamentum teres, contains the ligamentum teres and the small para-umbilical veins, and lies in front of the pyloric portion of the stomach. At its upper end the two layers of the falciform ligament separate from each other and expose a small triangular area on the superior surface of the liver which is devoid of peritoneum. The left layer becomes continuous with the anterior layer of the left triangular ligament : the right with the upper layer of the coronary ligament.

The *coronary ligament* is formed by the reflection of the peritoneum from the Diaphragm to the superior and posterior surfaces of the right lobe. It consists of an upper and a lower layer, continuous at their right extremities with the right triangular ligament of the liver but diverging widely to the left so as to enclose a large triangular area of the right lobe which is uncovered with peritoneum and is termed the ' bare area.' The upper layer is continuous with the right layer of the falciform ligament, skirts the upper end of the groove for the inferior vena cava anteriorly and then gradually descends from the posterior part of the upper surface to the upper part of the posterior surface. There it is continuous with the anterior layer of the right triangular ligament. The lower layer is continuous with the posterior layer of the right triangular ligament and passes almost horizontally along the lower limit of the posterior surface of the right lobe. In this situation the peritoneum may be reflected on to the upper part of the anterior surface of the right kidney instead of on to the Diaphragm beyond the margin of that organ. At its left extremity the lower layer of the coronary ligament passes in front of the lower end of the groove for the inferior vena cava and becomes continuous with the line of peritoneal reflexion from the right border of the caudate lobe, i.e. the right margin of the upper recess of the lesser sac of peritoneum.

The *left triangular ligament* of the liver passes from the upper surface of the left lobe upwards and backwards to the under surface of the Diaphragm. It consists of two closely applied layers of peritoneum which become continuous with each other when traced to the left, where the ligament ends in a free margin. Traced to the right the anterior layer becomes continuous with the left layer of the falciform ligament, and the posterior layer with the anterior layer of the lesser omentum at the upper end of the fissure for the ligamentum venosum. It is placed in front of the abdominal part of the œsophagus, the upper end of the lesser omentum and part of the fundus of the stomach.

The *right triangular ligament* is a short V-shaped fold which connects the lateral part of the posterior aspect of the right lobe to the Diaphragm. The apex of the V forms a free right, or lower, margin for the ligament, around which its two layers become continuous with each other. The ligament really constitutes the right limit of the coronary ligament.

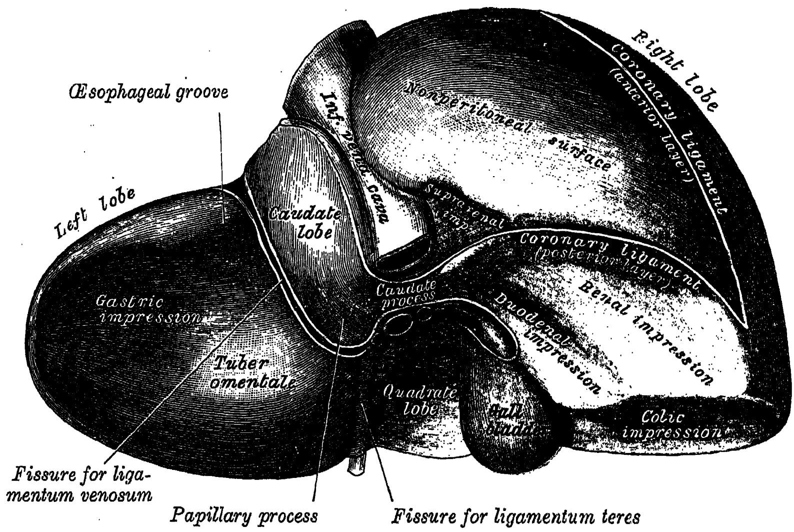
The *lesser omentum* has already been described (p. 1312) in detail. It will be sufficient to add that at the upper end of the fissure for the ligamentum venosum, its anterior layer becomes continuous with the posterior layer of the left triangular ligament, and its posterior layer with the line of reflexion of the

peritoneum from the upper end of the right border of the caudate lobe and so, indirectly, with the lower layer of the coronary ligament.

Surfaces.—The *superior surface* of the liver (fig. 1201) includes portions of the right and left lobes. It fits under the vault of the Diaphragm, and is covered with peritoneum, except over a small triangular area where the two layers of the upper part of the falciform ligament diverge. Its right and left portions are convex, but its central part presents a shallow *cardiac impression*, which corresponds with the position of the heart on the upper surface of the Diaphragm. It is related to the diaphragmatic pleura of the right side and the base of the right lung, to the pericardium and ventricular part of the heart, and, to a much smaller extent, to the diaphragmatic pleura of the left side and the base of the left lung.

The *anterior surface*, which is triangular in shape, also comprises portions of both right and left lobes, and is covered with peritoneum except at the line of attachment of the falciform ligament. A large part of this surface is in contact

FIG. 1202.—The posterior and inferior surfaces of the liver. (From a model by His.)



with the Diaphragm, which separates it, on the right side, from the pleura and the sixth to the tenth ribs and their cartilages and, on the left side, from the seventh and eighth costal cartilages. The thin anterior margin of the base of the lung is related to the upper part of this surface, but the relationship is much more extensive on the right than it is on the left side. The median part of the anterior surface of the liver lies behind the xiphoid process of the sternum and the anterior abdominal wall in the infracostal angle.

The *right surface* is convex from before backwards, and slightly so from above downwards. It is covered with peritoneum and is related to the right portion of the Diaphragm, which separates it from the right lung and pleura, and the right costal arches from the seventh to the eleventh inclusive. Over its upper third both lung and pleura intervene between the Diaphragm and the costal arches ; over its middle third only the costodiaphragmatic recess of the pleura is interposed ; over its lower third the Diaphragm is in actual contact with the costal arches.

The *posterior surface* includes portions of both right and left lobes ; it is thick and convex on the right, but thin on the left. A deep concavity marks its median portion and corresponds with the forward convexity formed by the vertebral column (fig. 1201). A large part of this surface of the right lobe is devoid of peritoneal covering and is attached to the Diaphragm by areolar tissue. This non-peritoneal surface constitutes the 'bare area' of the liver. It is triangular in outline and is limited above and below by the superior and inferior layers of the coronary ligament. Its base is formed by the deep groove for the inferior

vena cava, while its apex, directed downwards and laterally, corresponds with the right triangular ligament. The *groove for the inferior vena cava* is a deep depression, occasionally a complete tunnel, on the posterior surface of the liver and is devoid of peritoneal covering. It lodges the upper part of the vessel and its floor is pierced by the hepatic veins (p. 840). At its lower end the groove is separated from the porta hepatis in front by the caudate process. Immediately lateral to the lower end of the groove the ‘ bare area ’ presents a somewhat triangular impression on the formalin-hardened liver, which lodges the upper part of the right suprarenal gland and is therefore termed the *suprarenal impression*. On the left side of the groove for the inferior vena cava the *caudate lobe* occupies the rest of the posterior surface of the right lobe. It lies in the upper recess of the lesser sac of peritoneum (omental bursa), and is usually described as forming its anterior wall. This description is not quite accurate, because the peritoneum covering its posterior aspect is continued round its left border on to its anterior aspect, which forms the posterior wall of the fissure for the ligamentum venosum. The caudate lobe should therefore be regarded as projecting into the upper recess of the omental bursa from its right border. The posterior surface of the caudate lobe is related to the crura of the Diaphragm above the aortic opening and to the right phrenic artery, and is separated by them from the descending thoracic aorta. The *papillary process* often projects downwards in front of the origin of the cœliac artery.

The lips of the *fissure for the ligamentum venosum* separate the posterior aspect of the caudate from the posterior aspect of the left lobe. The fissure itself cuts deeply into the liver in front of the caudate lobe and contains the two layers of the lesser omentum. At its lower end it curves laterally below, or in front of, the papillary process, and reaches the left extremity of the porta hepatis. The *ligamentum venosum*, which is the fibrous remnant of the ductus venosus (p. 158), is attached below to the upper border of the left branch of the portal vein. It ascends in the floor of the fissure and passes laterally at the upper end of the caudate lobe to join the left hepatic vein near its point of entry into the inferior vena cava, or sometimes the vena cava itself.

The posterior aspect of the left lobe is marked by a shallow notch near the upper end of the fissure for the ligamentum venosum. It is occupied by the abdominal portion of the œsophagus and is termed the *œsophageal impression*. To the left of this impression the left lobe is related to a part of the fundus of the stomach.

The *inferior* or *visceral surface* is directed downwards, backwards and to the left, and, in the formalin-hardened organ, bears the imprints of the neighbouring viscera. It is invested with peritoneum except at the porta hepatis, the fissure for the ligamentum teres and the fossa for the gall-bladder. On the inferior surface of the left lobe, in direct continuity with the œsophageal impression, the *gastric impression* is moulded over the stomach. On the right of this impression there is a rounded ridge, the lower part of which is sometimes prominent and is termed the *omental tuberosity*. This ridge occupies the concavity of the lesser curvature of the stomach and is in contact with the lesser omentum. The *fissure for the ligamentum teres* is a cleft of variable depth which passes upwards and backwards from the corresponding notch on the inferior border of the liver to the left end of the porta hepatis where it meets the lower end of the fissure for the ligamentum venosum. It forms the left boundary of the quadrate lobe and may be, partially or completely, bridged over by a band of liver substance. Its floor lodges the *ligamentum teres of the liver*, which is the obliterated remains of the left umbilical vein in the fœtus (p. 687). Commencing at the umbilicus it ascends in the free margin of the falciform ligament to the inferior border of the liver, traverses the fissure and ends by joining the left branch of the portal vein at the left extremity of the porta hepatis.

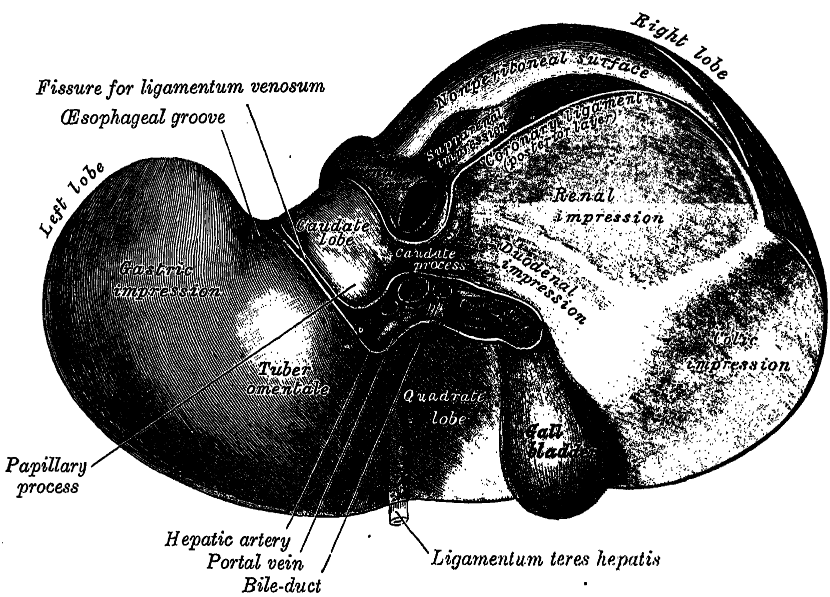
The gastric impression may be continued on to the anterior part of the *quadrate lobe*, which is hollowed out and moulded over the pyloric part of the stomach and the beginning of the duodenum, when these organs are dilated. The posterior, or upper, part of the quadrate lobe is in contact with the right free border of the lesser omentum and its contained structures. When the stomach is empty the quadrate lobe is related to the first part of the duodenum and a portion of the transverse colon.

The *porta hepatis* is placed on the inferior surface of the liver between the quadrate lobe in front and the caudate process behind. It is a deep fissure which runs transversely between the upper ends of the fissure for the ligamentum teres and the fossa for the gall-bladder. Through the porta hepatis the portal vein, the hepatic artery and the hepatic plexus of nerves enter the liver, and the right and left hepatic and the cystic ducts and some lymph vessels emerge. The hepatic ducts are situated anteriorly, the portal vein and its right and left branches posteriorly and the hepatic artery and its right and left branches are intermediate in position.

The *caudate process* connects the lower and lateral part of the caudate lobe to the remainder of the right lobe. It is placed behind the porta hepatis and in front of the inferior vena cava, and is covered with peritoneum. It forms the roof of the aditus to the lesser sac.

The *fossa for the gall-bladder* forms the right boundary of the quadrate lobe and extends from the inferior border of the liver to the right extremity of the

FIG. 1203.—The inferior surface of the liver. (From a model by His)



porta hepatis. It is usually shallow and devoid of peritoneal covering, but the breadth of this bare area is subject to individual variation.

To the right of the fossa for the gall-bladder, the inferior surface of the right lobe is marked by three impressions, viz. colic, renal and duodenal. The *colic impression* is related to the right colic flexure and is placed on the anterior part of the area, immediately adjoining the inferior border of the liver. The *renal impression* is usually well marked ; it is situated behind the colic impression and is separated from the neck and the adjoining part of the gall-bladder by the duodenal impression. It is related to the upper part of the anterior surface of the right kidney, and in its superomedial part to the lower pole of the right suprarenal gland. When the lower layer of the coronary ligament is reflected from the liver on to the right kidney, the renal impression extends for a short distance on to the lower part of the 'bare area.' The *duodenal impression* lies to the lateral side of the neck and adjoining part of the gall-bladder, and is related to the termination of the first part and the commencement of the second part of the duodenum.

The relations of the liver show considerable variation, for which posture and the movements of respiration are only partly responsible. *Those which have been enumerated refer to the body in the supine position.*

Vessels and Nerves.—The vessels connected with the liver are the portal vein, and the hepatic artery and veins.

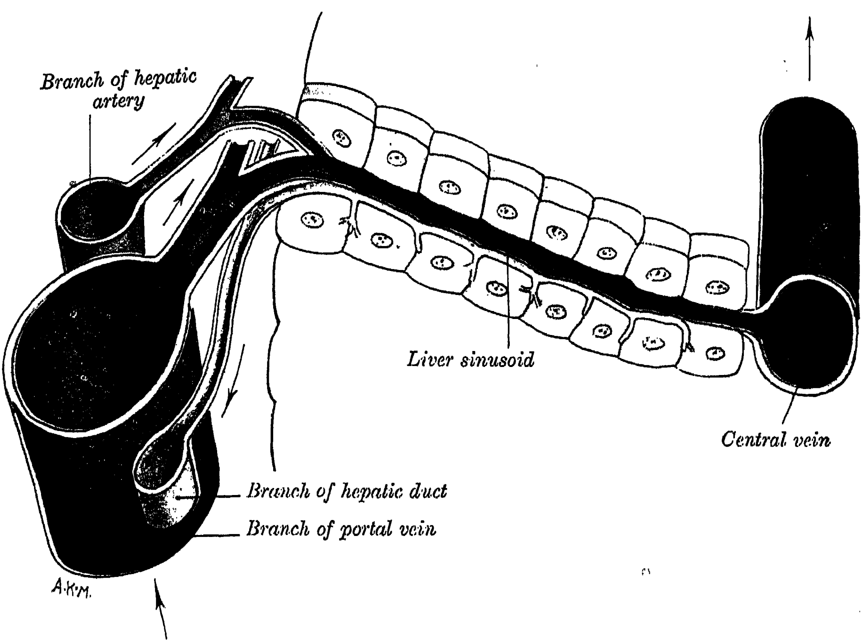
The *portal vein* and *hepatic artery,* accompanied by numerous nerves, ascend between the layers of the lesser omentum to the porta hepatis, where each divides into two branches; the *bile-duct* and lymph vessels descend from the porta hepatis between the layers of the same omentum. They are all enveloped in a loose areolar tissue, termed the *hepato-biliary capsule* (*of Glisson*), which accompanies the vessels in their course through the portal canals in the interior of the liver.

The *hepatic veins* (fig. 1204) convey the blood from the liver to the inferior vena cava, and are described on p. 840. They have very little cellular investment, but what there is binds them closely to the walls of the canals through which they run; so that, on section of the liver, they remain widely open and are solitary, and may be easily distinguished from the branches of the portal vein, which are more or less collapsed, and always accompanied by an artery and duct.

The *lymph vessels* of the liver are described on p. 867.

The *nerves* of the liver, derived from the left and right vagus, right phrenic, and sympathetic, enter at the porta hepatis and accompany the vessels and ducts to the

FIG. 1204.—Diagram to illustrate the circulation through a lobule of the liver.



Note that the sinusoids receive blood from both the hepatic artery and the portal vein. The central vein joins the system of hepatic veins and so drains into the inferior vena cava. The arrows indicate the direction of flow.

interlobular spaces. Here, according to Korolkow, the medullated fibres are distributed almost exclusively to the coats of the blood-vessels; while the non-medullated enter the lobules and ramify between the cells.

Structure of the liver.—The greater part of the liver is invested with peritoneum, which covers a thin capsule of connective tissue. With the naked eye the liver can be seen to consist of an enormous number of polyhedral lobules, each of which is about 1 mm. in diameter. In the pig each lobule is sharply marked off from those adjoining it by connective tissue septa, but in the human liver there are no such definite boundaries.

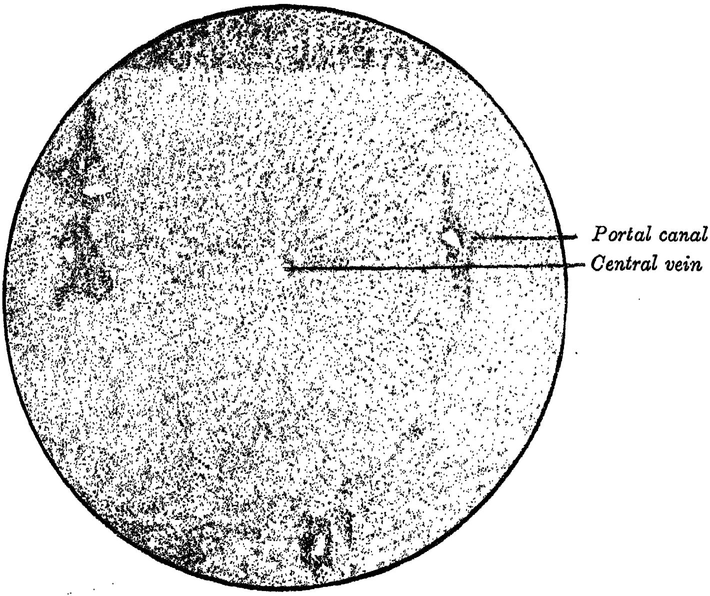
A *lobule* consists of a mass of cells, arranged in columns which radiate from a central vein (fig. 1205). Irregular blood-vessels (sinusoids) occupy the intervals between the columns.

A *liver-cell* is approximately cubical in shape, and is from 12μ to 25μ in diameter. It possesses one or two spherical nuclei, and its protoplasm usually contains granules of glycogen, and of a compound of iron. Fat droplets may also be present in the liver-cell.

Blood is conveyed to the liver by the portal vein and hepatic artery. These vessels enter the liver at the porta hepatis, and, as already stated, are enclosed together with the hepatic duct in a connective tissue sheath termed the hepato-biliary capsule. In the porta hepatis the portal vein, hepatic artery and common hepatic duct all divide into right and left

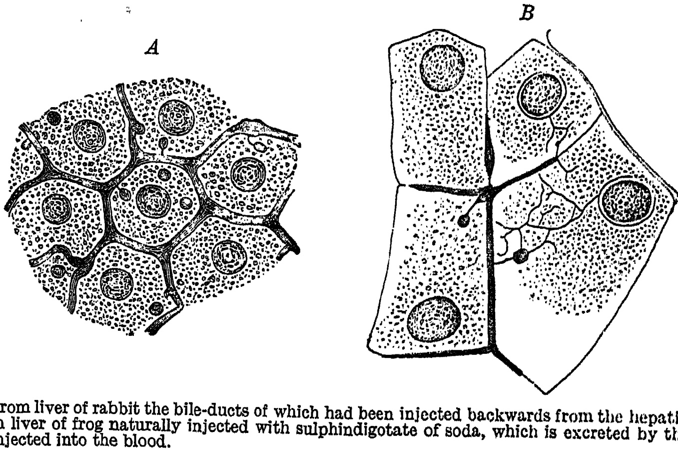
branches, and these branches subsequently ramify, in their connective tissue capsule, throughout the substance of the liver, and are accompanied by nerves and lymph vessels. The spaces occupied by these various structures are named *portal canals*. The smallest

FIG. 1205.—A section through a lobule of the human liver. Stained with hæmatoxylin and eosin. × 60.



branches of the portal vein form *interlobular plexuses* between the lobules, and from these plexuses capillary-like vessels, named sinusoids, run between the columns of liver-cells and open into the *central* veins in the centres of the lobules. The central veins join to form *sublobular veins*, and these unite to form the *hepatic veins* (fig. 1204), which drain the blood from the liver into the inferior vena cava.

FIG. 1206.—Sketches illustrating the manner in which bile passes from the hepatic cells into the intercellular bile-channels. (R. Heidenhain, after Kupffer.) (From Sharpey-Schafer's *Essentials of Histology*.)



A, from liver of rabbit the bile-ducts of which had been injected backwards from the hepatic duct; *B*, from liver of frog naturally injected with sulphindigotate of soda, which is excreted by the liver, when injected into the blood.

The *hepatic artery* conveys arterial blood to the connective tissue of the liver, to the walls of the subdivisions of the portal vein, and to the bile-ducts; its ultimate branches open into the interlobular plexuses and provide oxygenated blood for the liver cells.

The *sinusoids* are wider and more irregular than capillaries, and have an incomplete wall formed of branched cells (stellate cells of Kupffer) (p. 31). There is no lymph-space between the wall of the sinusoid and the liver-cells, and, in consequence of the gaps

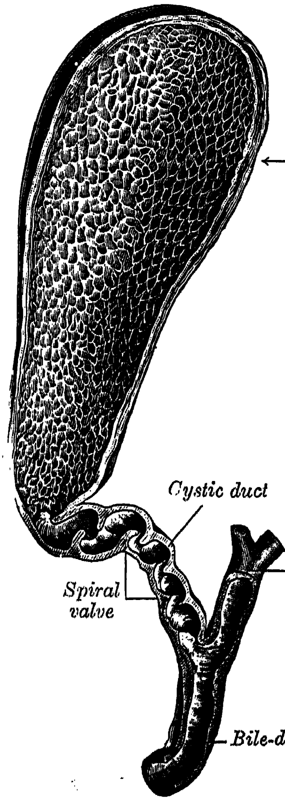
in the former, the blood comes into direct contact with the hepatic cells. Moreover, according to Herring and Simpson, minute channels penetrate the liver-cells, conveying the constituents of the blood into their substance.

The *bile ductules* do not penetrate the lobules, but receive minute canaliculi which convey the bile from the cells to the periphery of the lobules. These canaliculi, or *bile-capillaries,* are merely little channels or spaces between adjacent cells, and are always separated from the sinusoids by at least half the width of a liver-cell (fig. 1206).

Structure of the ductules.—The walls of the biliary ductules consist of a connective tissue coat, in which non-striped muscle-cells are arranged both circularly and longitudinally, and an epithelial layer, consisting of short columnar cells resting on a basement-membrane.

Nerve-fibrils are said to be distributed between the cells of the liver, and even to enter their substance.

Fig. 1207.—The gall-bladder and bile-ducts laid open. (Spalteholz.)



The Excretory Apparatus of the Liver

The excretory apparatus of the liver consists of (1) the *common hepatic duct,* formed by the junction of the right and left hepatic ducts, which leave the liver at the porta hepatis; (2) the *gall-bladder,* which serves as a reservoir for the bile; (3) the *cystic duct,* or duct of the gall-bladder; and (4) the *bile duct,* formed by the junction of the common hepatic and cystic ducts.

The **common hepatic duct.**—Two main ducts (right and left hepatic) issue from the liver and unite near the right end of the porta hepatis to form the common hepatic duct, which passes downwards for about 3 cm., and is joined at an acute angle by the cystic duct; by the union of the common hepatic with the cystic duct the bile duct is formed (fig. 1208). The common hepatic duct is on the right of the hepatic artery and in front of the portal vein.

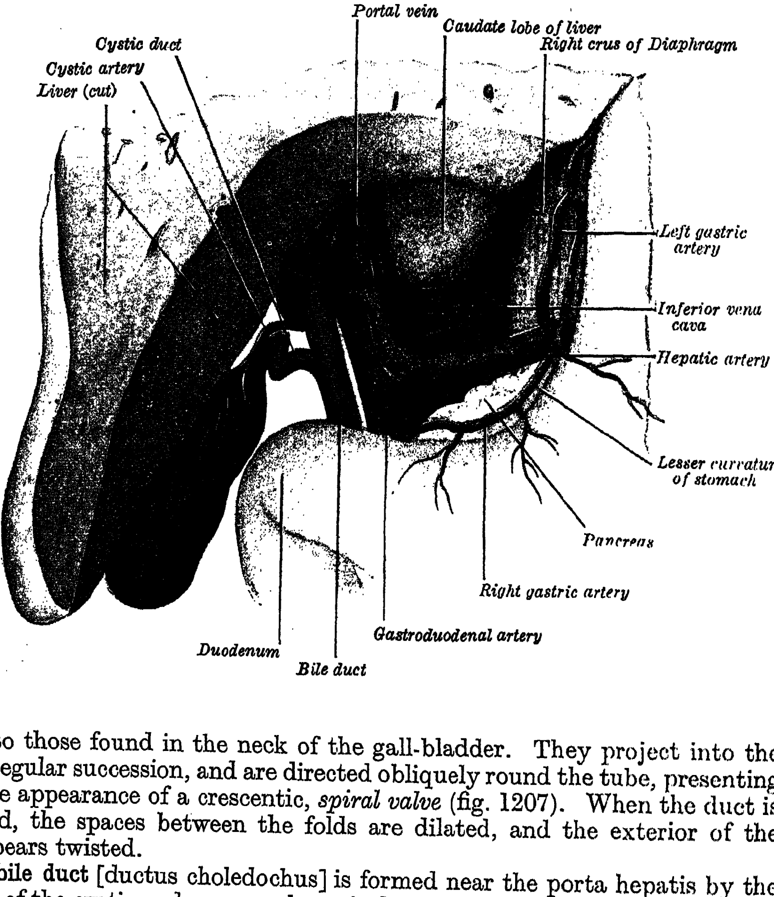
The **gall-bladder** [vesica fellea] (figs. 1203, 1207, 1208) is a conical or pear-shaped sac lodged in a fossa on the under surface of the right lobe and extending from near the right extremity of the porta hepatis to the inferior border of the liver. Its upper surface is attached to the liver by connective tissue; its under surface and sides are covered with peritoneum continued from the surface of the liver. Occasionally it is completely invested with peritoneum and may be connected to the liver by a short mesentery. It is from 7 cm. to 10 cm. long, 3 cm. broad at its widest part, and holds from 30 c.cm. to 50 c.cm. It is divided into a fundus, body and neck.

The *fundus,* or expanded end, is directed downwards, forwards and to the right. It projects beyond the inferior border of the liver, and comes into relationship with the posterior surface of the anterior abdominal wall below the ninth right costal cartilage, and behind the point where the lateral edge of the right Rectus abdominis crosses the costal margin; posteriorly the fundus is in relation with the transverse colon, near its commencement. The *body* is directed upwards, backwards and to the left; near the right end of the porta hepatis it is continuous with the neck. It is in relation by its upper surface with the liver; by its under surface, with the commencement of the transverse colon; and farther back usually with the upper end of the second part of the duodenum, but sometimes with the first part of the duodenum or pyloric end of the stomach. The *neck* is narrow; it curves upwards and forwards, and then, turning abruptly backwards and downwards, becomes continuous with the

cystic duct; at its point of continuity with the cystic duct there is a constriction. The neck is attached to the liver by areolar tissue in which the cystic artery is imbedded. The mucous membrane which lines the neck projects into its lumen in the form of oblique ridges, forming a sort of spiral valve.

The **cystic duct** (figs. 1203, 1208), from 3 cm. to 4 cm. long, passes backwards, downwards and to the left from the neck of the gall-bladder, and joins the common hepatic duct to form the bile duct; it runs parallel with and adheres to the common hepatic duct for a short distance before joining with it. The junction is usually situated immediately below the porta hepatis, but it may be at a considerably lower level. In the latter event the cystic duct lies in the right free margin of the lesser omentum. The mucous membrane lining its interior is thrown into a series of crescentic folds, from five to twelve in number,

FIG. 1208.—Drawing of a dissection to show the relations of the hepatic artery, bile-duct and portal vein in the lesser omentum.



similar to those found in the neck of the gall-bladder. They project into the duct in regular succession, and are directed obliquely round the tube, presenting much the appearance of a crescentic, *spiral valve* (fig. 1207). When the duct is distended, the spaces between the folds are dilated, and the exterior of the duct appears twisted.

The **bile duct** [ductus choledochus] is formed near the porta hepatis by the junction of the cystic and common hepatic ducts; it is about 7 cm. long, and of the diameter of a goose-quill.

It runs at first downwards, backwards and to the left anterior to the aditus to the lesser sac (epiploic foramen); here it lies in the right border of the lesser omentum, in front of the right edge of the portal vein, and on the right of the hepatic artery (fig. 1208). It passes behind the first part of the duodenum with the gastroduodenal artery on its left, and then runs in a groove on the upper and lateral part of the posterior surface of the head of the pancreas (fig. 1198); here it is situated in front of the inferior vena cava, and is sometimes completely imbedded in the pancreatic substance. At the left side of the second part of the duodenum it comes into contact with the pancreatic duct, and accompanies it into the wall of this part of the gut, and there the two ducts unite to form

the *ampulla of the bile duct*; the distal, constricted end of this ampulla opens into the second part of the duodenum on the summit of the duodenal papilla (fig. 1199) from 8 to 10 cm. from the pylorus (p. 1325).

Structure (fig. 1209).—The gall-bladder has three coats: serous, fibromuscular and mucous.

Fig. 1209.—Section of the wall of the gall-bladder. Human. (E. Sharpey-Schafer.) ×355. Photograph. Preparation by C. F. W. Illingworth. (From Sharpey-Schafer's *Essentials of Histology*.)

The *external* or *serous coat* is derived from the peritoneum; it completely invests the fundus, but covers only the under surfaces and sides of the body and neck.

The *fibromuscular coat*, a thin but strong layer, consists of dense, fibrous tissue, mixed with plain muscular fibres, which are disposed chiefly in a longitudinal direction, a few running transversely.

The *internal* or *mucous coat* is loosely connected with the fibrous layer. It is generally of a yellowish-brown colour, and is elevated into minute rugæ (fig. 1207). It is continuous through the common hepatic duct with that of the ducts of the liver, and through the bile-duct with that of the duodenum. Its epithelium is columnar, and actively absorbs fluid from the bile, rendering it more concentrated. It also secretes cholesterol.

The coats of the large biliary ducts are an external or fibrous, and an internal or mucous. The fibrous coat is composed of strong fibro-areolar tissue, with a certain amount of muscular tissue, arranged, for the most part, in a circular manner around the ducts. The mucous coat is continuous with the lining membrane of the hepatic ducts and gall-bladder, and also with that of the duodenum; and, like the mucous membrane of these structures, its epithelium is of the columnar variety. It is provided with numerous mucous glands, which are lobulated and open by minute orifices scattered irregularly in the larger ducts.

Applied Anatomy.—On account of its large size, its fixed position, and its friability, the liver is more frequently ruptured than any of the other abdominal viscera. The rupture may vary from a slight scratch to an extensive and complete laceration of its substance, dividing it into two parts. Sometimes an internal rupture, without laceration of the peritoneal covering, takes place, and such injuries are most susceptible to repair; but small tears of the surface may also heal; when, however, the laceration is extensive, death usually takes place from hæmorrhage, on account of the fact that the hepatic veins are contained in rigid canals in the liver-substance and are unable to contract, and moreover are unprovided with valves. The liver may also be torn by the end of a broken rib perforating the Diaphragm.

Abscess of the liver is of not infrequent occurrence and may enlarge in many different directions. Thus it has been known to burst into the lungs, when the pus is coughed up; or into the stomach, when the pus is vomited; it may burst into the colon, or duodenum; or, by perforating the Diaphragm, it may empty itself into the pleural cavity. It often makes its way forwards, and points on the anterior abdominal wall, and finally it may burst into the peritoneal or pericardial cavities.

Hydatid cysts are more often found in the liver than in any of the other viscera. The reason for this is not far to seek. The embryo of the egg of the Tænia echinococcus, being liberated in the stomach by the disintegration of its shell, bores its way through the gastric walls and usually enters a blood-vessel, and is carried by the blood-stream to the hepatic capillaries, where its onward course is arrested, and where it undergoes development into the fully formed hydatid.

The gall-bladder may become distended in cases of obstruction of the cystic duct or of the bile duct, or from a collection of gall-stones in its interior, thus forming a large tumour. The swelling is pear-shaped, and projects downwards and forwards towards the umbilicus. It moves with respiration, since it is attached to the liver.

Obstruction of the bile duct, apart from stone, is often due to occlusion of this canal by pressure of malignant growths, especially those commencing in the pylorus or pancreas. It is also seen following ulceration of the duct, cicatricial contraction of the scar tissue taking place. Enormous distension, both of the bile duct itself and of its radicles in the liver substance, may occur at times.

THE UROGENITAL SYSTEM

The urogenital apparatus consists of (*a*) the urinary organs for the secretion and discharge of the urine, and (*b*) the genital organs, which are concerned with the process of reproduction. The two groups are included in one system because, in the male, they are not entirely independent of one another, since one passage (viz. the urethra) serves to convey both the urine and the seminal fluid.

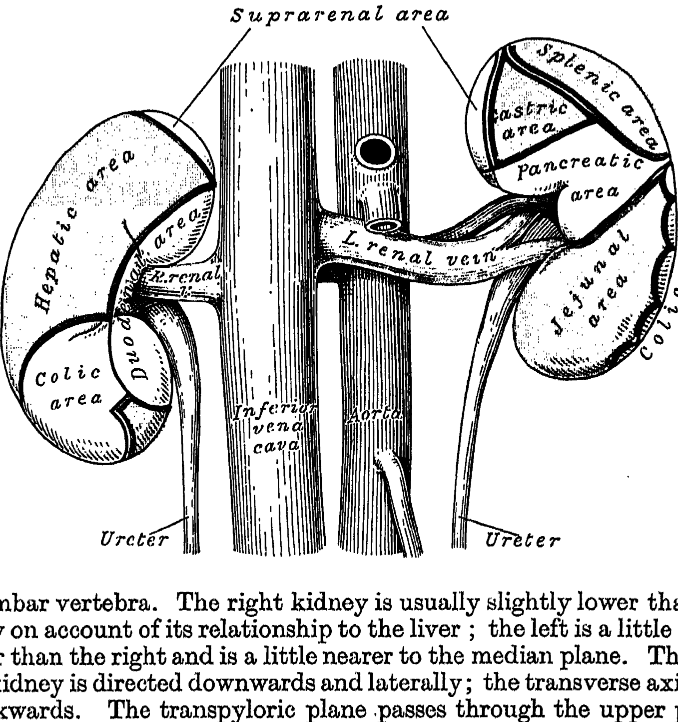
THE URINARY ORGANS

The urinary organs comprise (1) the *kidneys*, which secrete the urine ; (2) the *ureters*, which convey it to (3) the *urinary bladder*, where it is stored temporarily ; and (4) the *urethra*, through which it is discharged from the urinary bladder.

The Kidneys [Renes]

The **kidneys** are situated in the posterior part of the abdomen, one on each side of the vertebral column, behind the peritoneum ; they are surrounded by a mass of fat and some loose areolar tissue. Their upper ends are on a level with the upper border of the twelfth thoracic vertebra, their lower, with the

Fig. 1210.—The anterior surfaces of the kidneys, showing the areas of contact of the neighbouring viscera.



third lumbar vertebra. The right kidney is usually slightly lower than the left, probably on account of its relationship to the liver ; the left is a little longer and narrower than the right and is a little nearer to the median plane. The long axis of each kidney is directed downwards and laterally; the transverse axis, laterally and backwards. The transpyloric plane passes through the upper part of the hilum of the right kidney, and through the lower part of the hilum of the left.

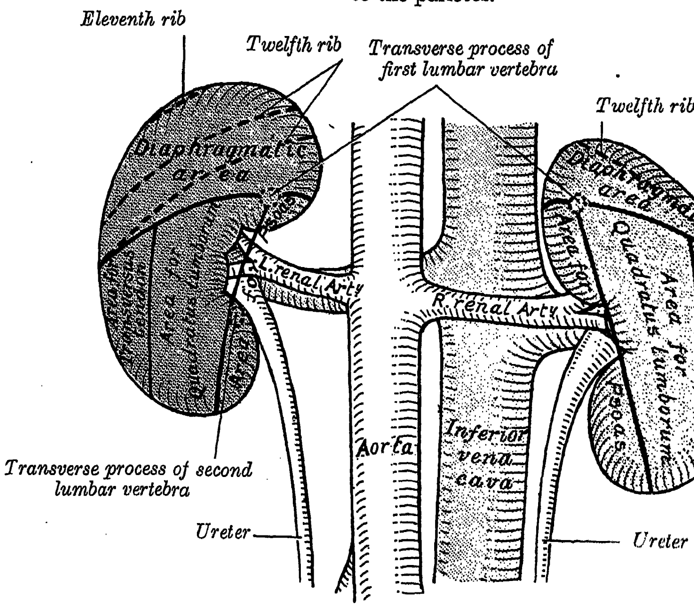
Each kidney is about 11 cm. in length, 6 cm. in breadth, and about 3 cm. in thickness. In the adult male the weight of the kidney varies from 125 gm. to 170 gm. ; in the adult female from 115 gm. to 155 gm.

The kidney has a characteristic form, and presents for examination two surfaces, two borders, and an upper and a lower end.

Relations.—The *anterior surface* (figs. 1197, 1210) of each kidney is convex, and looks forwards and laterally. Its relations to adjacent viscera differ on the two sides of the body.

(*a*) *Anterior surface of right kidney.*—A narrow portion at the upper extremity is in contact with the right suprarenal gland. The gland may overlap the upper pole, or the upper part of the medial border, or it may occupy a position midway between the two. A large area just below this and involving about three-fourths of the surface, lies in the renal impression on the inferior surface of the right lobe of the liver, and a narrow but somewhat variable area near the medial border is in contact with the second part of the duodenum. The lower part of the anterior surface is in contact laterally with the right colic flexure, and medially, as a rule, with a part of the small intestine. The area in relation with small intestine and almost the whole of the area in contact with the liver are covered with peritoneum; the suprarenal, duodenal and colic areas are devoid of peritoneum.

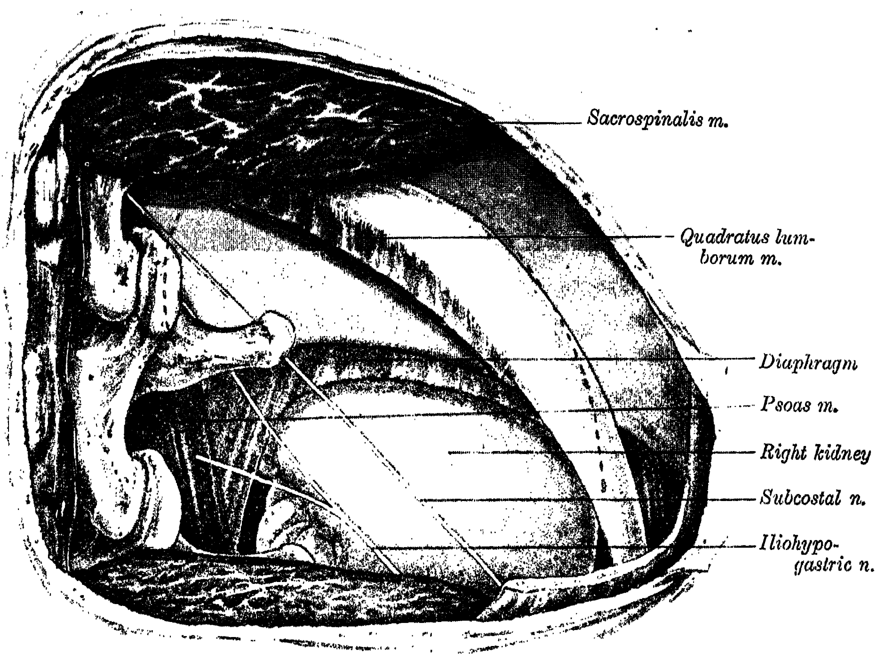
FIG. 1211.—The posterior surfaces of the kidneys, showing the areas of relation to the parietes.



(*b*) *Anterior surface of left kidney.*—A small area along the upper part of the medial border is in relation with the left suprarenal gland, and the upper two-thirds or less of the lateral half of the anterior surface are in contact with the renal impression on the spleen. A somewhat quadrilateral field, about the middle of the anterior surface, is in contact with the body of the pancreas and the splenic vessels behind it. Above this there is a small triangular portion, between the suprarenal and splenic areas, which is in contact with the stomach. The size of the gastric area is very variable. It is diminished, or may even be absent, when the left kidney lies at an abnormally low level, or when the obliquity of the body of the pancreas is accentuated. Below the pancreatic and splenic areas the lateral part is in relation with the left colic flexure and the commencement of the descending colon, the medial with the first coils of the jejunum. The jejunal area is always extensive but, as the descending colon is normally in a condition of contraction, the colic area forms an irregular, narrow strip immediately adjoining the lateral border of the kidney. The area in contact with the stomach is covered with the peritoneum of the lesser sac, while those in relation to the spleen and the jejunum are covered with the peritoneum of the greater sac; behind the peritoneum of the jejunal area some branches of the superior left colic vessels are related to the kidney. The suprarenal, pancreatic, and colic areas are devoid of peritoneum.

The *posterior surface* (figs. 1211 to 1214) of each kidney is directed backwards and medially. It is imbedded in areolar and fatty tissue, and is devoid of peritoneal covering. It lies upon the Diaphragm, the medial and lateral arcuate ligaments (lumbocostal arches), the Psoas major, the Quadratus lumborum, and the tendon of origin of the Transversus abdominis, the subcostal vessels, and the last thoracic, iliohypogastric and ilioinguinal nerves. The right kidney rests upon the twelfth rib, the left usually on the eleventh and twelfth. The Diaphragm separates the kidney from the pleura, which dips down to form the costodiaphragmatic recess (fig. 1212), but frequently the muscular fibres of the Diaphragm are defective or absent over a triangular area immediately above the lateral arcuate ligament, and when this is so the perinephric areolar tissue is in contact with the diaphragmatic pleura.

FIG. 1212.—The right kidney, exposed from behind.



The *blue* area represents the pleura, the broken *red* line the upper part of the kidney.

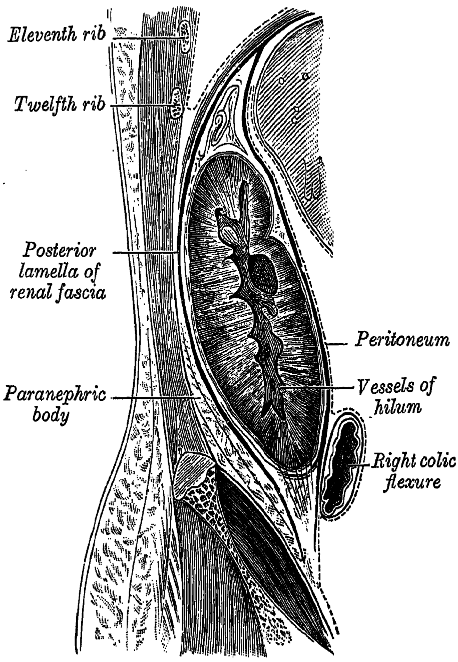
The *upper end* of the kidney is thick and round, and is nearer the median plane than the lower; it is surmounted by the suprarenal gland, which covers also a small portion of the anterior surface. The *lower end*, smaller and thinner than the superior, extends to within 5 cm. of the iliac crest.

The *lateral border* is convex; that of the left kidney is in contact, at its upper part, with the spleen and, at its lower part, with the descending colon; that of the right with the right lobe of the liver.

The *medial border* is concave in the centre and convex at each end; it is directed a little downwards and forwards. In its central part there is a deep vertical fissure, termed the ***hilum***, which is bounded by an anterior and a posterior lip, and transmits the renal vessels and nerves and the funnel-shaped upper end (*pelvis*) of the ureter. The relative positions of the main structures in the hilum are as follows: the renal vein is in front, the renal artery in the middle and the pelvis of the ureter behind. As a rule one of the branches of the renal artery enters the hilum behind the ureteral pelvis, and it is not uncommon to find one of the tributaries of the renal vein issuing from the hilum in the same plane. Above the hilum the medial border is in relation with the suprarenal gland, below with the commencement of the ureter.

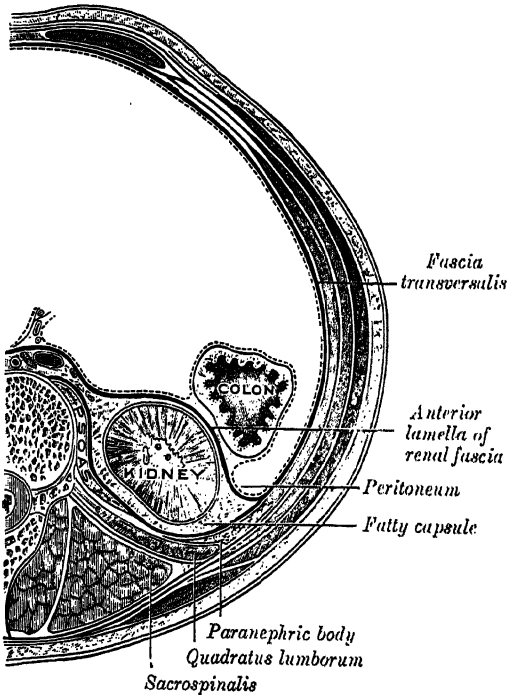
The hilum leads into a central recess or cavity named the *renal sinus,* which is lined by a continuation of the capsule of the kidney and is almost entirely filled by the ureteral pelvis and renal vessels; numerous nipple-like elevations, termed the *renal papillæ,* mark the wall of the sinus. Within the sinus the pelvis of the ureter divides into two, sometimes three, large branches which are named the *calyces majores,* and each of these divides again into several short branches named the *calyces minores* (fig. 1216). In all, there are usually from seven to thirteen of these lesser calyces; each expands as it approaches the wall of the renal sinus, and the expanded end is indented and moulded round from one to three renal papillæ (Pl. II, fig. 2). The wall of the expanded end of the calyx is firmly adherent to the capsule lining the renal sinus; it is perforated by the collecting tubules which open on the summits of the renal papillæ.

FIG. 1213.—A sagittal section through the posterior abdominal wall showing the relations of the renal fascia. (After Gerota.)



The kidney and its vessels are imbedded in a mass of fatty tissue, termed the *renal fat,* which is thickest at the borders of the kidney and is prolonged through the hilum into the renal sinus. The fibro-areolar tissue surrounding the kidney and the renal fat is condensed to form a sheath and is termed the *renal fascia.*

FIG. 1214.—A transverse section, showing the relations of the renal fascia. (After Gerota.)

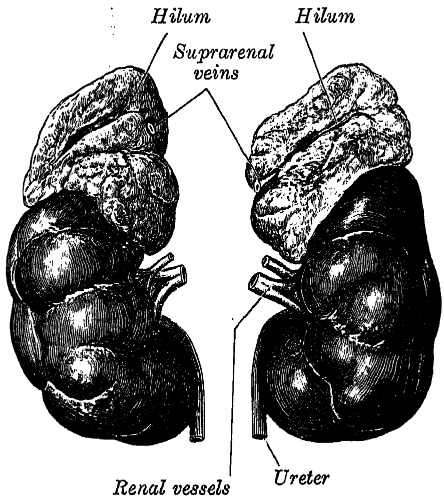


At the lateral border of the kidney the two layers of the sheath are fused. The anterior layer is carried medially in front of the kidney and its vessels, and at the level of the latter is continuous over the aorta with the corresponding layer of the opposite side.* The posterior layer extends medially behind the kidney and in front of the fascia on the Quadratus lumborum and Psoas major, and is attached to the vertebræ and intervertebral discs. Above the suprarenal gland the two layers of the renal fascia fuse, and are connected with the fascia of

* A. H. Southam (*Quarterly Journal of Medicine,* Number 64, July 1923, p. 283) maintains that the anterior layer of the renal fascia is not continued across the median plane. He says it "can be traced as far as the pancreas and to the root of the mesentery, and there becomes lost in the connective tissue elements present in this situation."

the Diaphragm; below the kidney they remain separate, and are gradually lost in the extraperitoneal tissue of the iliac fossa. The renal fascia is connected to the fibrous capsule of the kidney by numerous trabeculæ, which traverse the fatty capsule, and are strongest near the lower end of the organ. Behind the renal fascia there is a considerable quantity of fat, which is sometimes termed the *paranephric body*. The kidney is held in position partly through the attachments of the renal fascia but principally by the apposition of the neighbouring viscera.

FIG. 1215.—The kidneys and suprarenal glands of a new-born child. Anterior aspect.



In the fœtus the kidney consists of about twelve distinct lobules (fig. 1215), but in the adult these are fused and the kidney presents a uniformly smooth surface.

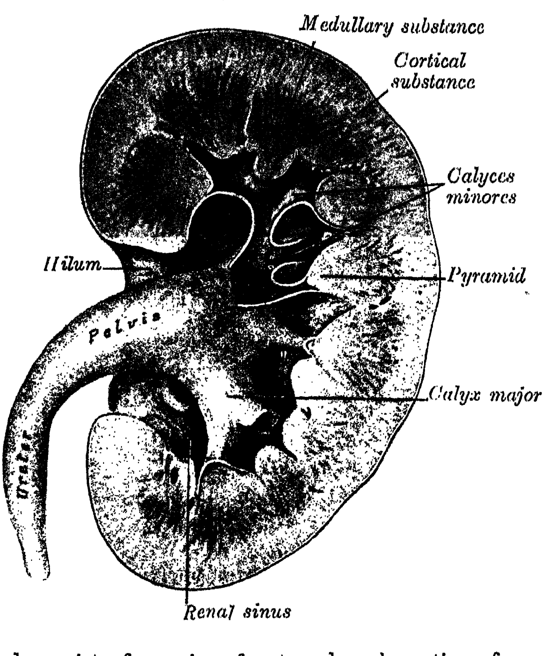
General structure of the Kidney. The kidney is invested by a fibrous capsule which is easily stripped off; an incomplete layer of smooth muscular fibres lies beneath the fibrous capsule.

If a vertical section be made from its lateral to its medial border, and the loose tissue and fat removed from around the vessels and the excretory duct, the *renal sinus* will be seen surrounded at all parts but one by the proper kidney-substance (fig. 1216). The fibrous capsule is prolonged into the sinus round the lips of the hilum, to become continuous with the outer coat of the pelvis of the ureter.

The kidney is composed of an internal, medullary and an external, cortical substance.

The *medullary substance* consists of a series of pale, striated, conical masses, termed the *renal pyramids*, the bases of which are directed towards the circumference of the kidney, while their apices converge towards the renal sinus, where they form prominent papillæ projecting into the interior of the calyces, each calyx minor receiving from one to three papillæ.

FIG. 1216.—A vertical section through a kidney, to show the pelvis of the ureter and calyces, and the cortical and medullary substance.



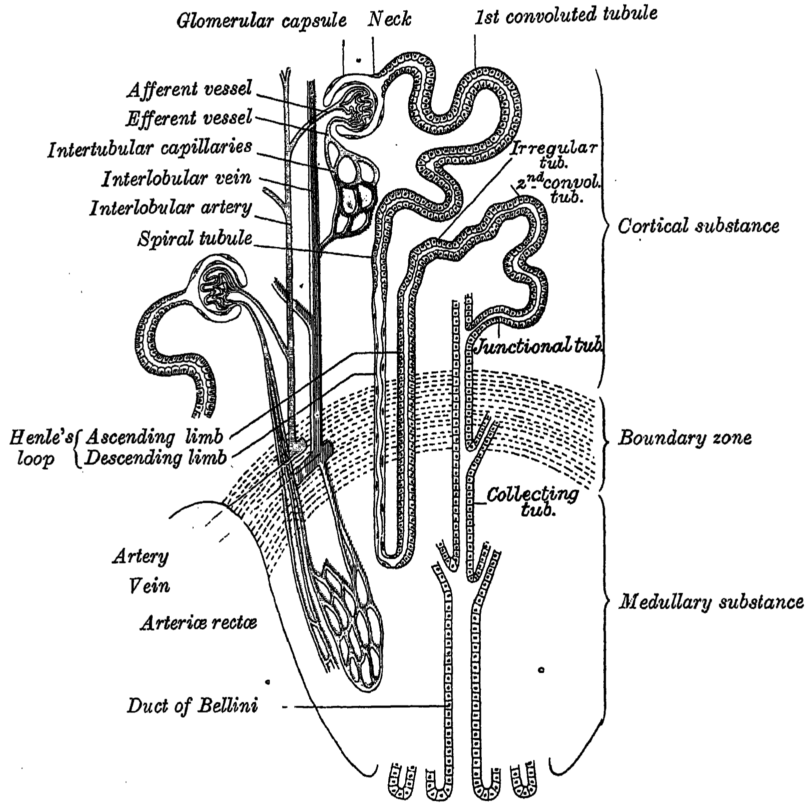
The *cortical substance* is reddish-brown in colour, and soft and granular in consistence. It lies immediately beneath the fibrous capsule, arches over the bases of the pyramids, and dips in between adjacent pyramids towards the renal sinus. The parts dipping in between the pyramids are named the *renal columns*, while the portions which connect the renal columns with each other and intervene between the bases of the pyramids and the fibrous capsule are called the *cortical arches*. If the cortex be examined with a lens, it will be seen to consist of a series of lighter-coloured, conical areas, termed *medullary rays* (fig. 1220), and a darker-coloured intervening substance, which from the complexity of its structure is named the *convoluted part*. The rays gradually taper towards the circumference of the kidney, and consist of a series of outward prolongations from the base of each renal pyramid.

The cortical and medullary substances are made up of renal tubules and blood-vessels, united and bound together by a connecting stroma.

Minute Anatomy.—The *renal tubules* (fig. 1217) commence in the cortical substance, and after pursuing a very tortuous route through the cortical and medullary substances finally

end at the apices of the renal pyramids by open mouths. If the surface of one of the papillæ be examined with a lens, it will be seen to be studded over with minute openings, the orifices

FIG. 1217.—A scheme of a renal tubule and its vascular supply.



of the renal tubules, from sixteen to twenty in number, and if pressure be made on a fresh kidney, urine will be seen to exude from these orifices. The tubules commence in the convoluted part and renal columns as the *renal* (*Malpighian*) *corpuscles*, which are small rounded masses of a deep red colour, averaging about 0·2 mm. in diameter. Each of these bodies is

FIG. 1218.—The distribution of the blood-vessels in the cortex of kidney.

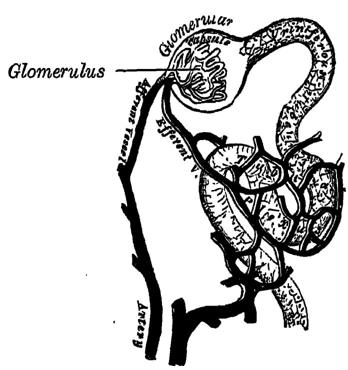
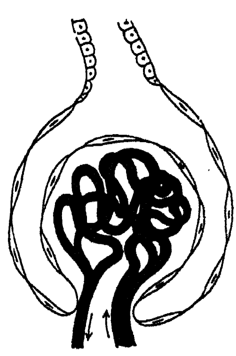


FIG. 1219.—A glomerulus.



composed of two parts: a central *glomerulus* of vessels, and a membranous envelope, termed the *glomerular capsule*, which is the small pouch-like commencement of a renal tubule.

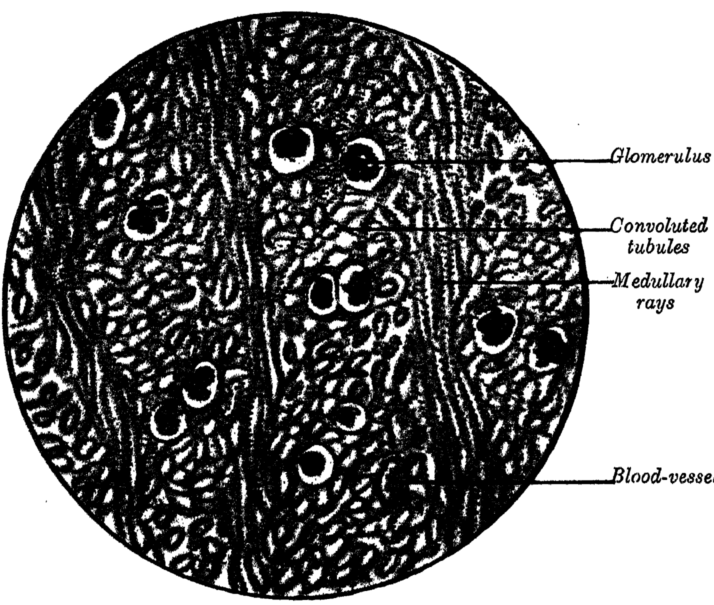
The *glomerulus* is a lobulated tuft of convoluted, capillary blood-vessels, held together by scanty connective tissue. This capillary network is derived from a small arterial twig (the *afferent vessel*), which enters the capsule, generally at a point opposite to that at which

the latter is connected with the tubule; the *efferent vessel* emerges from the capsule at the same point. The afferent vessel is usually the larger of the two (figs. 1218, 1219).

The *glomerular capsule* is the blind, expanded end of the renal tubule, indented for the reception of the glomerulus. It consists of a basement-membrane, lined by a single layer of flattened epithelial cells. Thus between the glomerulus and the outer layer of the capsule there is a space lined by a continuous layer of flattened cells; this cavity varies in size according to the state of secretion and the amount of fluid present in it. In the fœtus and young subject the lining epithelial cells are polyhedral or columnar.

Each *renal tubule* consists of the following parts: (1) the *glomerular capsule*, already described, (2) a constricted portion or *neck*, (3) the *first convoluted tubule*, (4) the *spiral tubule*, which takes a course towards the medulla, (5) the *descending limb of Henle's loop*, narrower than the preceding, and running into the medullary substance, where it turns to form (6) the *loop of Henle*, (7) the *ascending limb of Henle's loop*, broader than the descending limb, which re-enters the cortical substance, (8) an angular segment, termed the *irregular* or *zig-zag tubule*, (9) the *second convoluted tubule*, (10) the *junctional tubule*, which opens into (11), the *collecting tubule* (fig. 1217).

FIG. 1220.—A radial section through the cortex of a human kidney. Stained with hæmatoxylin and eosin. ×100.



The *straight* or *collecting tubules* commence in the medullary rays of the cortex; they unite at short intervals with one another; the terminal tubes present a considerable increase in calibre, and are known as the *ducts of Bellini*; they open finally on the summit of a papilla.

Structure of the renal tubules.—The renal tubules consist of a basement-membrane lined with epithelium. In the neck the epithelium is continuous with that lining the glomerular capsule, and like it consists of flattened cells each containing an oval nucleus (fig. 1219). The two convoluted tubules, the spiral and zig-zag tubules, and the ascending limb of Henle's loop are lined with a type of epithelium which is histologically similar in all. The cells are somewhat columnar in shape and dovetail into one another on their lateral aspects. Each has a striated border next the lumen of the tube; its substance is granular, the granules in the outer portion being arranged in vertical rows. The nucleus is spherical and situated about the centre of the cell. In the descending limb of Henle's loop the epithelium resembles that found in the glomerular capsule and the commencement of the tube, consisting of flat, clear, epithelial plates, each with an oval nucleus. The nuclei alternate on opposite surfaces of the tubule so that the lumen remains fairly constant.

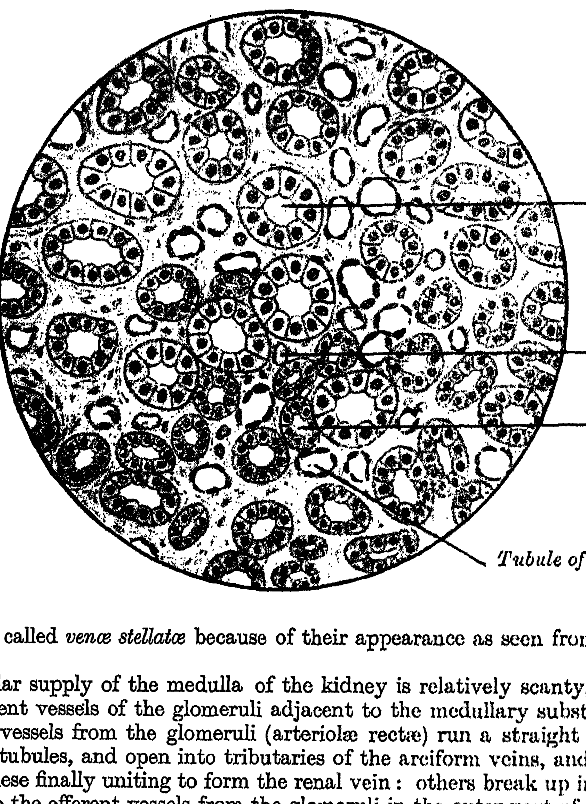
In the collecting tubule the epithelium is clear and cubical: in its papillary portion the cells are columnar and transparent (fig. 1221).

The renal blood-vessels.—Before entering the kidney, each artery divides into four or five branches which at the hilum lie mainly between the renal vein and pelvis of the ureter, the vein being in front, the pelvis behind; one branch usually lies behind the pelvis. Each vessel gives off some small branches to the suprarenal glands, to the ureter, and to the surrounding cellular tissue and muscles. One or two *accessory renal arteries* may arise from the abdominal aorta, either above or below the renal artery. Such vessels do not enter the hilum, but pierce the upper or lower parts of the kidney. The branches of the renal artery,

while in the sinus, give off a few twigs for the nutrition of the surrounding tissues, and divide into *lobar arteries*, one for each renal papilla. Before entering the kidney substance each lobar artery divides into two (sometimes three) *interlobar arteries* which run towards the cortex on each side of the pyramid. At the junction between the cortex and the medulla each interlobar artery divides dichotomously into branches which run at right angles to the parent stem. These are termed the *arciform arteries*, and it is to be noted that the interlobar and arciform arteries to each lobe do not anastomose with the corresponding arteries of neighbouring lobes. The arciform arteries give off a large number of straight arteries [*interlobular*], arranged vertically to the surface, each of which gives off a number of lateral branches, afferent vessels of the glomeruli, or *glomerular arteries*. Each interlobular artery with its branches and associated glomeruli resembles a string of red currants.

From the capillaries of each glomerulus an efferent vessel, smaller than the afferent vessel, arises and divides to form a second set of capillaries which run between the tubules and are called *intertubular capillaries*. These unite to form *interlobular veins*, which discharge into the tributaries of the *interlobar veins* running with the interlobar arteries. Each interlobular vein begins beneath the fibrous capsule of the kidney by the convergence of

FIG. 1221.—A transverse section through a pyramid of a human kidney. Stained with hæmatoxylin and eosin. ×400.



smaller veins, called *venæ stellatæ* because of their appearance as seen from the surface of the organ.

The vascular supply of the medulla of the kidney is relatively scanty, and is derived from the efferent vessels of the glomeruli adjacent to the medullary substance. Many of these efferent vessels from the glomeruli (arteriolæ rectæ) run a straight course between the collecting tubules, and open into tributaries of the arciform veins, and so reach interlobar veins, these finally uniting to form the renal vein: others break up into intertubular capillaries, like the efferent vessels from the glomeruli in the outer part of the cortex.

The circulation through the kidney is primarily a glomerular circulation, and all the branches which arise from the arciform and interlobular arteries terminate in glomeruli.*

In the living subject a pale streak, known as Brödel's line, marks the dorsal part of the lateral convex border of the kidney and indicates on the surface of the organ the boundary zone between the areas of distribution of the anterior and the posterior branches of the renal artery.

Nerves of the kidney.—The nerves of the kidney, although small, are about fifteen in number. They have small ganglia developed upon them, and are derived from the renal plexus, which is formed by branches from the cœliac plexus, the lower and lateral part of the cœliac ganglion and aortic plexus, and from the lesser and lowest splanchnic nerves. The nerves which supply the kidney are derived from the tenth, eleventh and twelfth thoracic segments of the spinal cord. The nerves communicate with the testicular plexus, a circumstance which may explain the occurrence of pain in the testis in affections of the kidney.

* D. B. MacCallum, *American Journal of Anatomy*, vol. xxxviii. 1926. R. A. Moore, *Anatomical Record*, vol. xl. 1928.

They accompany the renal artery and its branches, and are distributed to the blood-vessels and to the cells of the urinary tubules.

The *lymph vessels* of the kidney are described on p. 871.

Connective tissue, or *intertubular stroma*.—Although the tubules and vessels are closely packed, a small amount of connective tissue, continuous with the fibrous capsule, binds them firmly together and supports the blood-vessels, lymph vessels and nerves.

Applied Anatomy.—In badly nourished people or in those who have become emaciated the renal fat is deficient and the kidney may become displaced; this condition, which occurs more frequently in women than in men, on account of the greater laxity of the abdominal walls, is termed movable kidney.

Injuries of the kidney are generally due to some severe crushing force, as from being run over by a heavy waggon or cart, or from the abdomen being compressed between the buffers of two railway carriages. When a laceration occurs on the posterior surface of the organ, infiltration of blood and urine takes place into the retroperitoneal tissue; when the laceration is in front, the peritoneum may be torn and extravasation of blood and urine may take place into the peritoneal cavity.

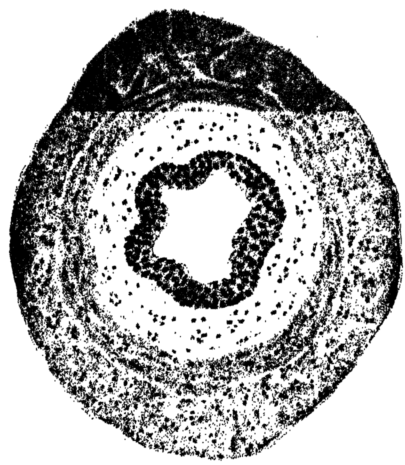
Incisions into the kidney for the purpose of displaying the interior of the renal pelvis are made along Brödel's line. The plane of the incision passes through the relatively avascular area (p. 1368) and undue hæmorrhage is thus avoided.

The early pelvic position of the kidney (p. 186) may persist, and in these cases the organ usually derives its blood-supply from the common iliac artery. The development of the kidney is partly arrested and the hilum lies on its anterior aspect.

The Ureters

The ureters are the two tubes which convey the urine from the kidneys to the urinary bladder. Each measures from 25 cm. to 30 cm. in length, and is a thick-walled, narrow, cylindrical tube which commences within the renal sinus as a funnel-shaped dilatation, termed the *pelvis of the ureter* (fig. 1216). It runs downwards and medially in front of the Psoas major, passes into the pelvic cavity, and opens into the base of the urinary bladder.

Fig. 1222.—A transverse section through the ureter. Stained with hæmatoxylin and eosin.



The *pelvis of the ureter* has already been described (p. 1364).

The *abdominal part* of the ureter lies behind the peritoneum on the medial portion of the Psoas major, which intervenes between it and the tips of the transverse processes of the lumbar vertebræ (Pl. II, fig. 2). It is crossed obliquely by the testicular (or ovarian) vessels. It enters the pelvic cavity by crossing either the end of the common, or the beginning of the external, iliac vessels.

At its origin the *right* ureter is usually covered by the second part of the duodenum; in its course downwards it lies to the right of the inferior vena cava, and is crossed by the right colic and the ileocolic vessels, while near the inlet of the pelvis it passes behind the lower part of the mesentery and the terminal part of the ileum. The *left ureter* is crossed by the left colic vessels, and near the inlet of the pelvis passes behind the pelvic colon and its mesentery, lying in the posterior wall of the recess of the pelvic mesocolon (intersigmoid recess).

The *pelvic part* of the ureter runs at first downwards on the lateral wall of the pelvic cavity, under cover of the peritoneum, and along the anterior border of the greater sciatic notch. It lies in front of the internal iliac (hypogastric) artery, and medial to the obturator nerve and the umbilical, obturator, inferior vesical, and middle rectal (hæmorrhoidal) arteries. Opposite the lower part of the greater sciatic foramen it runs medially and forwards, and reaches the lateral angle of the urinary bladder, where it is situated in front of the upper end of the seminal vesicle (and at a distance of about 5 cm. from the opposite ureter);

here the vas deferens crosses in front of it to gain its medial side, and the vesical veins surround it (fig. 1224). Finally, the ureters run obliquely through the wall of the bladder and open by slit-like apertures into the cavity of that viscus at the lateral angles of the trigone (fig. 1228). When the bladder is distended the openings of the ureters may be about 5 cm. apart, but when it is empty and contracted the distance between them is diminished by one-half. Owing to their oblique course through the coats of the bladder, the upper and lower walls of the terminal portions of the ureters become closely applied to each other when the bladder is distended, and, acting as valves, prevent regurgitation of urine. It should be noted that the peritoneum is closely applied to the medial side of the pelvic part of the ureter, except at its termination, where the vas deferens and, sometimes, one or two small vessels intervene (fig. 1223).

In the *female*, the pelvic part of the ureter forms the posterior boundary of a shallow depression named the *ovarian fossa*, in which the ovary is situated. It runs medially and forwards below the lower part of the broad ligament of the uterus, and passes lateral to the cervix uteri and the upper part of the vagina. It then lies for a short distance in front of the vagina, and finally pierces the wall of the bladder obliquely. In this part of its course it is accompanied for about 2·5 cm. by the uterine artery, which then crosses in front of the ureter and ascends between the two layers of the broad ligament. The ureter is distant about 2 cm. from the side of the cervix of the uterus.*

The ureter is sometimes duplicated on one or both sides, and the two tubes may remain distinct as far as the base of the urinary bladder ; they rarely open separately into the bladder cavity. The normal constrictions of the ureter have already been described (p. 186).

Structure (fig. 1222).—The ureter is composed of three coats: fibrous, muscular and mucous.

The *fibrous coat* is continuous at one end with the fibrous capsule of the kidney in the floor of the renal sinus ; while at the other it is lost on the wall of the bladder.

In the pelvis of the ureter the *muscular coat* consists of two layers, longitudinal and circular: the longitudinal fibres become lost upon the sides of the papillæ at the extremities of the calyces ; the circular fibres surround the medullary substance in the same situation. In the ureter proper the muscular fibres are very distinct, and are arranged in three layers: an external longitudinal, a middle circular, and an internal, less distinct than the other two, but having a general longitudinal direction.

The *mucous coat* is smooth, and presents a few longitudinal folds which become effaced by distension. It is continuous with the mucous membrane of the bladder below, while it is prolonged over the papillæ of the kidney above. It consists of fibrous tissue containing many elastic fibres, and covered with transitional epithelium. The continuation of the epithelium over the renal papillæ is columnar in type.

The *arteries* supplying the ureter are branches from the renal, testicular (or ovarian), internal iliac and inferior vesical arteries.

The *lymph vessels* of the ureter are described on p. 872.

The *nerves* are derived from the inferior mesenteric, spermatic (or ovarian), and pelvic plexuses ; through these plexuses fibres are derived from the lower three thoracic and first lumbar segments of the spinal cord. Small ganglia and isolated ganglion-cells are found in the fibrous and muscular coats.

Applied Anatomy.—Stones may become impacted in any part of the ureter, but this occurs most commonly at the points where the tube is normally constricted (p. 186). When a stone is impacted in the ureter, it gives rise to attacks of *renal colic*, probably due to spasmodic attempts on the part of the ureteral musculature to dislodge it. The pain is experienced in the cutaneous areas innervated from those segments of the spinal cord which also supply the ureter. It commences in the loin in the area supplied by the tenth thoracic nerve and shoots downwards and forwards to the groin, affecting in succession areas

* J. C. Brash (*British Medical Journal*, Oct. 28, 1922) says:

" The relation of the last portion of the ureter to the vagina is variable. There is usually a portion of the ureter in front of the vagina, lying for a short distance in the connective tissue between the vagina and bladder, and then in the wall of the bladder itself.

" With the vagina and bladder symmetrically related to each other this portion of the ureter is equal on the two sides ; but deviation from the symmetrical position is the rule. The result is an increase of this portion of the ureter on one side and a corresponding decrease on the other. There is frequently no ureter in front of the vagina on one side, and therefore a much longer portion than usual on the other side.

" In the majority of specimens examined, it is the left ureter that has the greatest relation to the vagina, and it is occasionally found crossing the middle line of the vagina. . . . It must not be forgotten, however, that occasionally the position may be reversed."

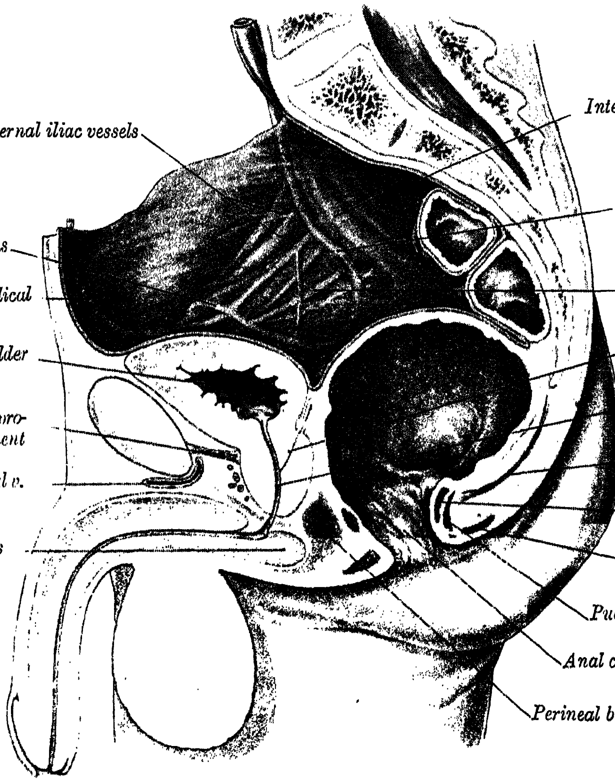
supplied by the eleventh and twelfth thoracic and the first lumbar nerves. Finally, it shoots into the testis of the same side.

The Urinary Bladder [Vesica Urinaria]

The urinary bladder (fig. 1223) is a sac which acts as a reservoir for the urine ; its size and position vary with the amount of fluid that it contains, and also with the state of distension of the neighbouring viscera. "The mean capacity of the living urinary bladder in the male adult is 220 c.c., varying from 120 c.c. to 320 c.c." *

When the empty bladder is firmly contracted, it presents the form of a

Fig. 1223.—A median sagittal section through the male pelvis.



flattened tetrahedron. It has a base or fundus, an apex, a superior and two inferolateral surfaces and a neck. The *base* is triangular in shape, and is directed downwards and backwards towards the rectum, from which it is separated by the rectovesical fascia, the vesiculæ seminales, and the terminal portions of the vasa deferentia. The *apex* is directed forwards towards the upper part of the symphysis pubis, and from it the median umbilical ligament (urachus) is continued upwards on the back of the abdominal wall to the umbilicus ; the peritoneum folded over this ligament forms the median umbilical fold. The *superior surface* is triangular, covered by peritoneum, and is in relation with the pelvic colon and the terminal coils of the ileum. It is bounded on each side by a lateral border which separates it from the inferolateral surface, and behind by a posterior border, represented by a line joining the two ureters, which intervenes between it and the basal aspect. The lateral borders run from the ureters to the apex, and from these borders the peritoneum extends to the walls of the pelvis. On each side of the bladder there is a peritoneal depression named the *paravesical fossa* (fig. 1157). The *inferolateral surfaces* are directed downwards and laterally, and are uncovered by peritoneum. They are separated in front from

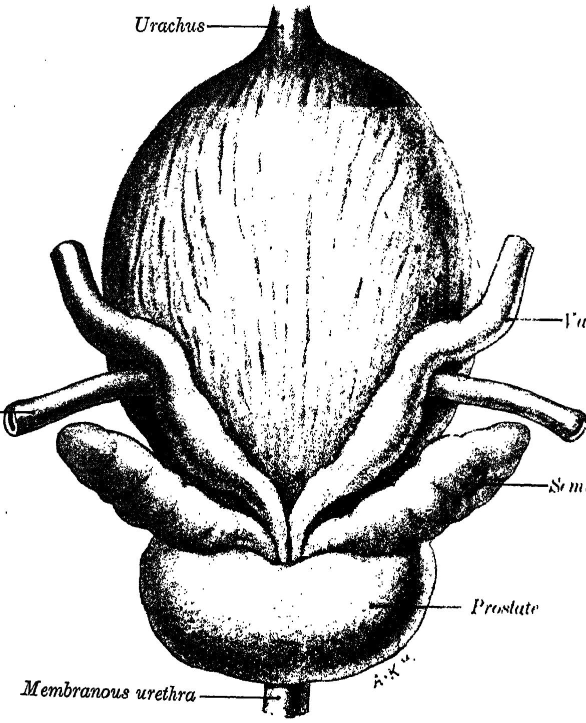
* A. Ralph Thompson, *Journal of Anatomy*, vol. liii.

the symphysis pubis by a mass of fatty tissue named the *retropubic pad* ; behind, they are in contact, on each side, with the fasciæ covering the Levator ani and Obturator internus. The neck of the bladder rests upon and is in direct continuity with the base of the prostate ; it is pierced by the internal urethral orifice. It is subject to but little alteration in position with varying conditions of the bladder and rectum, and lies a little above the plane of the pelvic outlet.

When the bladder is empty it is placed entirely within the pelvis, below the level of the obliterated umbilical arteries, and of the portions of the vasa deferentia which are in contact with the lateral wall of the pelvis.

As the bladder fills, its superior surface gradually rises into the abdominal cavity, carrying with it its peritoneal covering, and at the same time rounding off and finally obliterating the posterior and lateral borders. When the bladder is distended it assumes an ovoid form, the long diameter being directed up-

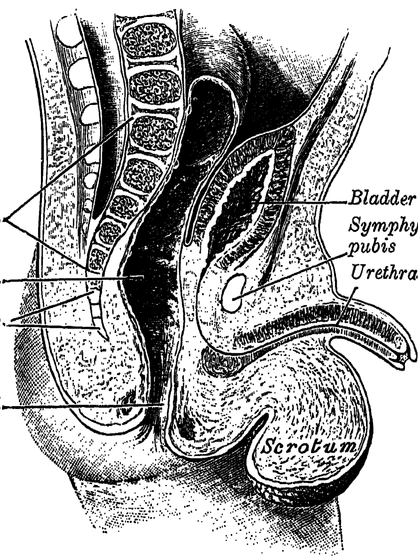
FIG. 1224.—The urinary bladder and prostate, viewed from above and behind.



wards and forwards. In this condition it presents a posterosuperior, an antero-inferior and two lateral surfaces, a base, and a summit ; owing to the obliteration of the posterior and lateral borders the four surfaces are not sharply marked off from one another. The posterosuperior surface is directed upwards and backwards, and is covered with peritoneum ; its posterior part is separated from the rectum by the rectovesical pouch, while its anterior part is in contact with coils of the small intestine. The antero-inferior surface is devoid of peritoneum, and rests against the pubic bones and the posterior surface of the anterior abdominal wall. The lower parts of the lateral surfaces are destitute of peritoneum, and are in contact with the lateral walls of the pelvis. The line of peritoneal reflection from the lateral surfaces is raised to the level of the obliterated umbilical arteries. The base, being more or less fixed, is only slightly lowered. It exhibits, however, a narrow triangular area, which is separated from the rectum merely by the rectovesical fascia. This area is bounded below by the prostate, above by the rectovesical fold of peritoneum, and laterally by the vasa deferentia. The vasa deferentia frequently come in contact with each other above the prostate, and when this occurs the lower part of the triangular area is obliterated. The line of reflection of the peritoneum

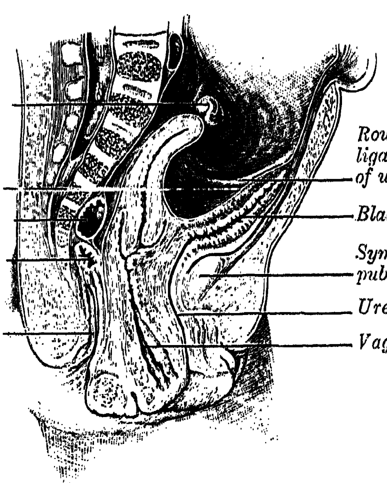
from the rectum to the bladder undergoes little or no change when the latter is distended; it is situated about 10 cm. from the anus. The summit of the bladder is directed upwards and forwards above the point of attachment of the median umbilical ligament, and hence the peritoneum, which follows the ligament, forms a pouch of varying depth between the summit and the anterior abdominal wall.

FIG. 1225.—A sagittal section through the pelvis of a new-born male child.



In the new-born child (figs. 1225, 1226) the internal urethral orifice is at the level of the upper border of the symphysis pubis; the bladder therefore lies relatively at a much higher level in the infant than in the adult. Its anterior surface "is in contact with about the lower two-thirds of that part of the abdominal wall which lies between the symphysis pubis and the umbilicus" (Symington *). Its fundus is clothed with peritoneum as far as the level of the internal orifice of the urethra. Although the bladder of the infant is usually described as an abdominal organ, Symington pointed out that only about one-half of it lies above the plane of the inlet of the pelvis. Disse maintains that the internal urethral orifice sinks rapidly during the first three years of life, and then more slowly until the ninth year, after which it remains stationary until puberty, when it again slowly descends and reaches its adult position.

FIG. 1226.—A sagittal section through the pelvis of a new-born female child. Some coils of the small intestine separated the uterus from the bladder.



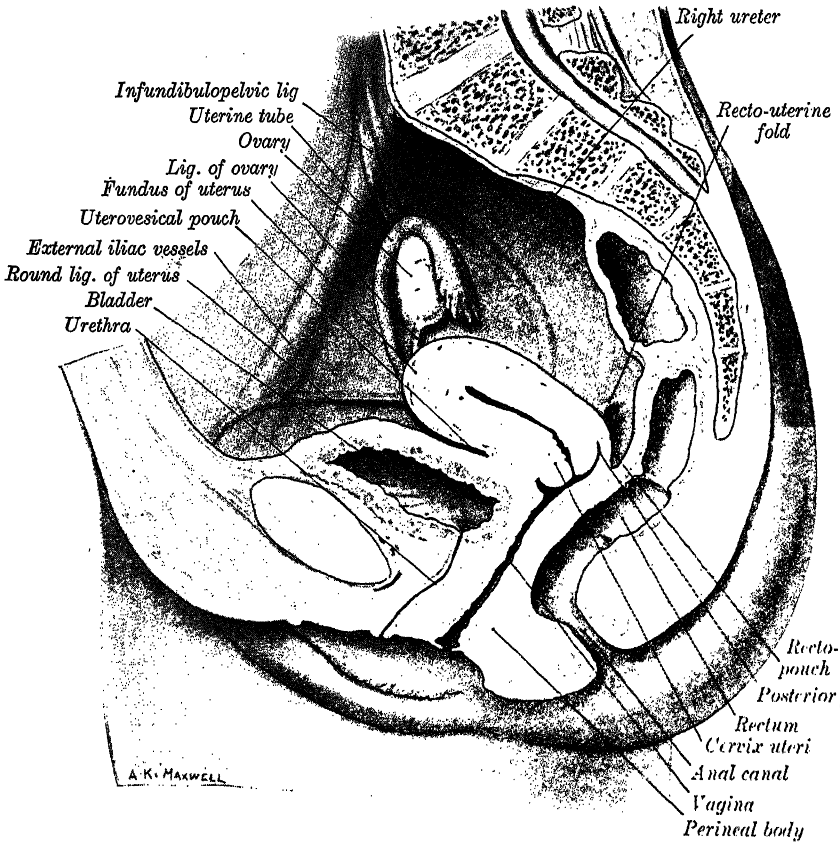
In the female, the bladder is in relation behind with the uterus and the upper part of the vagina (fig. 1227). It is separated from the anterior surface of the body of the uterus by the utero-vesical pouch, but below the level of this pouch it is connected to the front of the cervix uteri and the upper part of the anterior wall of the vagina by fibro-areolar tissue. When the bladder is empty the uterus rests upon its superior surface.

Ligaments.—Each side of the bladder is connected to the tendinous arch of the pelvic fascia (p. 574) by a condensation of fibro-areolar tissue which is often termed the *lateral true ligament* of the bladder. Anteriorly the same tissue forms two thickened bands, on each side of the median plane, termed the lateral and medial puboprostatic ligaments. The *lateral puboprostatic ligament* extends from the anterior end

* *The Anatomy of the Child.*

of the tendinous arch of the pelvic fascia downwards and medially to blend with the upper part of the sheath of the prostate; the *medial puboprostatic ligament* is attached to the back of the pubic bone near the middle of the symphysis and passes downwards and backwards to the sheath of the prostate, forming the floor of the retropubic space. The *apex* of the bladder is joined to the umbilicus by the remains of the urachus, which forms the *median umbilical ligament*. The lumen of the urachus persists throughout life and is lined by modified, transitional epithelium. It frequently communicates with the cavity of the bladder.* As the veins of the prostatic venous plexus (pudendal plexus) stream backwards from the lateral borders of the base of the bladder to join the internal iliac veins, they are enveloped in fibro-areolar tissue, which is sometimes termed the *posterior ligaments* of the bladder.

Fig. 1227.—A medial sagittal section through the female pelvis.



From the superior surface of the bladder the peritoneum is carried off in a series of folds which are sometimes termed the false ligaments of the bladder. Anteriorly there are three folds: the *median umbilical fold* on the median umbilical ligament, and two *lateral umbilical folds* on the obliterated umbilical arteries (fig. 1157). The reflections of the peritoneum from the bladder to the side walls of the pelvis form the lateral false ligaments while the sacrogenital folds (p. 1308) constitute the posterior false ligaments.

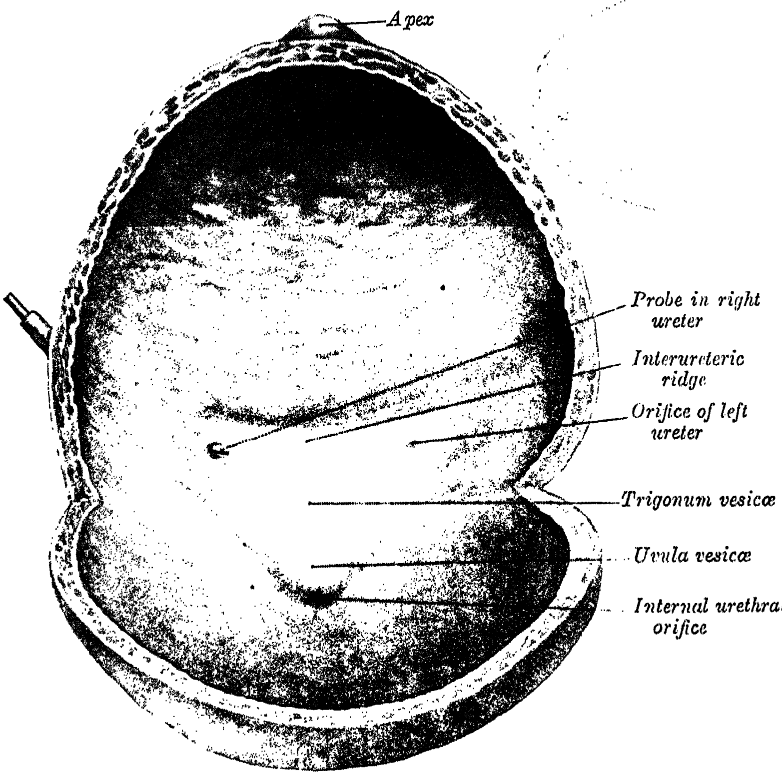
The interior of the bladder (fig. 1228).—The mucous membrane which lines the bladder is, over the greater part of the viscus, loosely attached to the muscular coat, and appears folded when the bladder is contracted: the folds are effaced when the bladder is distended. Over a small triangular area, named the *trigone of the bladder* [*trigonum vesicæ*], immediately above and behind the internal orifice of the urethra, the mucous membrane is firmly bound to the

* R. C. Begg, *Journal of Anatomy*, vol. lxiv. 1930.

muscular coat, and is always smooth. The anterior angle of the trigone is formed by the internal orifice of the urethra : its posterolateral angles by the orifices of the ureters. The base of the trigone is formed by a slightly curved ridge, termed the *interureteric ridge*, which connects the two ureteral orifices and is produced by the continuation into the bladder wall of the inner longitudinal coats of the ureters. The lateral parts of this ridge extend beyond the openings of the ureters ; they are named the *ureteric folds* and are produced by the terminal portions of the ureters as they run obliquely through the bladder-wall. When the living bladder is examined with a cystoscope the interureteric ridge appears as a pale band, and forms an important guide during the operation of introducing a catheter into the ureter.

The *orifices of the ureters* are placed at the posterolateral angles of the trigone of the bladder, and are usually slit-like in form. In the contracted bladder they are about 2·5 cm. apart and about the same distance from the

FIG. 1228.—The interior of the bladder. Viewed from in front.



internal urethral orifice ; in the distended bladder these measurements may be increased to about 5 cm.

The *internal urethral orifice* is placed at the apex of the trigone, in the most dependent part of the bladder, and is usually somewhat crescentic in form ; the mucous membrane immediately behind it exhibits a slight elevation, caused by the median lobe of the prostate and termed the *uvula vesicæ*.

Structure (fig. 1229).—The bladder is composed of four coats : serous, muscular, submucous and mucous.

The *serous coat* is a partial one, and is derived from the peritoneum. It invests the superior surface and the upper parts of the lateral surfaces, and is reflected from these on to the abdominal and pelvic walls.

The *muscular coat* consists of three layers of unstriped muscular fibres : an external and an internal of longitudinal fibres, and a middle of circular fibres.

The fibres of the *external longitudinal layer* pass in a more or less longitudinal manner, up the inferolateral surfaces of the bladder, over its apex, and then descend along its base to become attached to the prostate and its capsule in the male, and to the front of the vagina in the female. Some of the longitudinal fibres are carried on to the front of the rectum, and

are named the *Musculus rectovesicalis*. Others traverse the medial puboprostatic ligaments and are attached to the lower part of the pelvic surface of the pubis on each side. They are sometimes termed the *musculi pubovesicales*. At the sides of the bladder the fibres are arranged obliquely and intersect one another.

The fibres of the *middle circular layer* are very thinly and irregularly scattered on the body of the organ, and, although to some extent placed transverse to its long axis, are for the most part arranged obliquely. Towards the lower part of the bladder, round the internal urethral orifice, they are disposed in a thick circular layer, forming the *Sphincter vesicæ*, which is continuous with the muscular fibres of the prostate.

The *internal longitudinal layer* is thin, and its fasciculi have a reticular arrangement, but with a tendency to assume for the most part a longitudinal direction.

Two bands of oblique fibres, originating behind the orifices of the ureters, converge to the back part of the prostate, and are inserted by means of a fibrous process into the median

FIG. 1229.—A vertical section through the wall of the bladder (human).

lobe of the organ. They are the *muscles of the ureters*, described by Sir C. Bell, who supposed that during the contraction of the bladder they serve to retain the oblique direction of the ureters, and so prevent the reflux of the urine into them.

The *submucous coat* consists of a layer of areolar tissue, connecting together the muscular and mucous coats, and intimately united with the latter.

The *mucous coat* is thin, smooth, and of a pale rose colour. It is continuous above with that of the ureters, and below with that of the urethra; the epithelium covering it is of the transitional variety. The loose texture of the submucous layer allows the mucous coat to be thrown into folds or *rugæ* when the bladder is empty. Over the trigonum vesicæ the mucous membrane is closely attached to the muscular coat, and is not thrown into folds, but is smooth and flat. There are no true glands in the mucous membrane of the bladder, though certain mucous follicles which exist, especially near the neck of the bladder, have been regarded as such.

Vessels and Nerves.—The principal *arteries* of supply to the bladder are the superior and inferior vesical, derived from the anterior trunk of the internal iliac (hypogastric) artery. The obturator and inferior gluteal arteries also send small branches to it, and in the female additional branches are derived from the uterine and vaginal arteries.

The *veins* form a complicated plexus on the inferolateral surfaces near the prostate, and pass backwards in the posterior ligaments of the bladder to end in the internal iliac veins.

The *lymph vessels* are described on p. 873.

The *nerves* of the bladder are (1) fine medullated fibres from the second, third, and fourth sacral nerves (parasympathetic), and (2) non-medullated fibres from the hypogastric

plexus (sympathetic). They are connected with ganglia in the outer and submucous coats, and are finally distributed, all as non-medullated fibres, to the muscular layer and epithelial lining of the viscus.

Applied Anatomy.—When the bladder is distended, it may be ruptured by violence applied to the abdominal wall, without any injury to the bony pelvis, or it may be torn in cases of fracture of the pelvis. The rupture may be either intraperitoneal or extraperitoneal: that is, may implicate the superior surface of the bladder in the former case, or one of the other surfaces in the latter.

The muscular coat of the bladder undergoes hypertrophy in cases in which there is any obstruction to the flow of urine. Under these circumstances the bundles of which the muscular coat consists become much increased in size, and, interlacing in all directions, give rise to what is known as the *fasciculated bladder.* Between these muscular bundles the mucous membrane may bulge out, forming sacculi, constituting *diverticula of the bladder,* and in these little pouches phosphatic concretions may collect, forming *encysted calculi.*

Various forms of tumour have been found springing from the wall of the bladder, and in doubtful cases the cystoscope proves a valuable aid in diagnosis. This instrument consists of a tube in which is fixed a small electric light, the wires of which run through the shaft of the instrument. When it is introduced down the urethra, the bladder can be examined with the eye, and a villous growth or other tumour, a calculus, or an ulcer can be detected; or the orifices of the ureters can be examined, and renal hæmaturia diagnosed, and it can be definitely settled from which kidney the blood comes. The cystoscope can be used to catheterise the ureter, for the purpose of obtaining a specimen of urine from either kidney, or to ascertain the condition of both kidneys when it is proposed to remove one. Ureteric bougies opaque to x-rays can be passed and photographed. The pelvis of the kidney can be distended with 25 per cent. sodium bromide through the ureter and its shape photographed. More satisfactory results are now obtained from X-ray photographs taken after the intravenous injection of uroselectan.

Puncture of the distended bladder may be performed above the symphysis pubis without wounding the peritoneum.

Access to the bladder, for the purpose of removing calculi or an enlarged prostate, is almost always effected by the suprapubic route, the perineal operation being rarely resorted to. In the female, owing to the shortness of the urethra and its ready dilatability, calculi and foreign bodies and new growths, when of small size, may be removed by the urethral route. Over-dilatation of the female urethra may cause incontinence of urine.

The Male Urethra (figs. 1223, 1230)

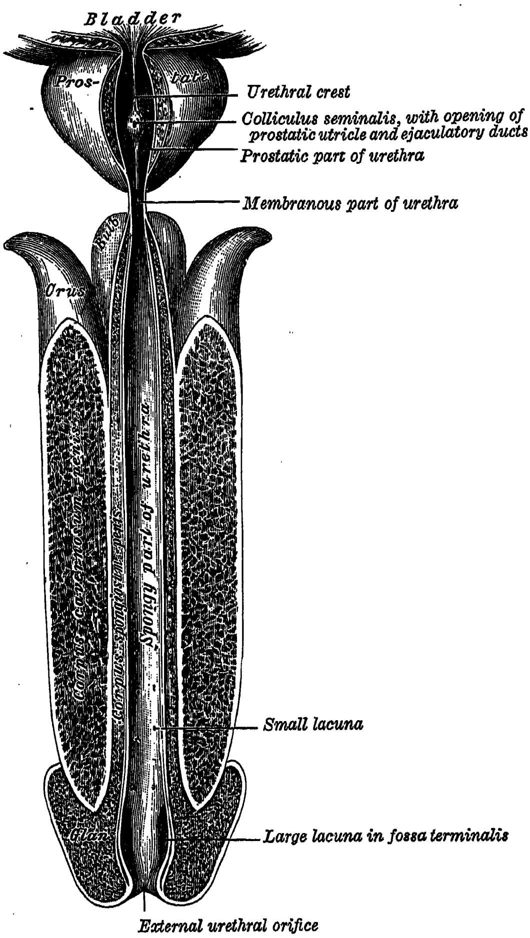
The **male urethra**, from 18 cm. to 20 cm. long, extends from the internal urethral orifice in the urinary bladder to the external urethral orifice at the end of the penis. It is divided into three portions, viz. *prostatic, membranous,* and *spongy* (cavernous), and presents a double curve in the ordinary flaccid state of the penis (fig. 1223). Except during the passage of fluid along it, the urethral canal is a mere slit or cleft; in the prostatic portion the slit is transversely arched; in the membranous portion, irregular or stellate; in the spongy portion, transverse; while at the external orifice it is sagittal.

The **prostatic portion**, which is the widest and most dilatable part of the urethra, is about 3 cm. long, and runs almost vertically through the prostate from its base to its apex; it lies nearer the anterior than the posterior surface of the prostate. It is widest in the middle, and is narrowest below, where it joins the membranous portion: on transverse section it is horseshoe-shaped with the convexity directed forwards.

Upon the posterior wall or floor a narrow median longitudinal ridge is formed by an elevation of the mucous membrane and its subjacent tissue and is termed the *urethral crest* (fig. 1236). On each side of the crest there is a shallow depression, termed the *prostatic sinus,* the floor of which is perforated by the *orifices of the prostatic ducts.* Near the middle of the urethral crest the *colliculus seminalis* forms an elevation on which the slit-like orifice of the prostatic utricle is situated; on each side of this orifice there is the small opening of the ejaculatory duct. The *prostatic utricle* is a cul-de-sac about 6 mm. long, which runs upwards and backwards in the substance of the prostate behind the median lobe. Its walls are composed of fibrous tissue, muscular fibres, and mucous membrane; the latter presents the openings of numerous small glands. It is developed from the united lower ends of the paramesonephric (Mullerian) ducts, and is therefore homologous with the vagina of the female (p. 190). The ejaculatory ducts are described on p. 1386.

The **membranous portion** is the shortest, least dilatable, and, with the exception of the external orifice, the narrowest part of the urethra. It runs downwards and forwards, with a slight concavity, from the prostate to the bulb of the penis (fig. 1223), perforating the perineal membrane about 2·5 cm. below and behind the pubic symphysis. The hinder part of the bulb of the penis lies in close apposition with the perineal membrane (inferior fascia of the urogenital diaphragm), but its upper portion diverges somewhat from this fascia; the anterior wall of the membranous urethra is thus prolonged for a short distance below the perineal membrane before it reaches the penile bulb; it measures about 2 cm. in length, while the posterior wall is only 1·25 cm. long.

FIG. 1230.—The male urethra laid open on its anterior (upper) surface.



The membranous portion of the urethra is surrounded by the fibres of the Sphincter urethræ (p. 580). In front of it the deep dorsal vein of the penis enters the pelvis between the transverse perineal ligament and the inferior (arcuate) pubic ligament; near its termination the bulbo-urethral glands are placed one on each side.

The **spongy (cavernous) portion** is contained in the corpus spongiosum penis (corpus cavernosum urethræ). It is about 15 cm. long, and extends from the end of the membranous portion to the external urethral orifice on the glans penis. Commencing below the perineal membrane it passes forwards to the front of the lower part of the symphysis pubis; and then, in the flaccid condition of the penis, it bends downwards and forwards. It is narrow, with a uniform diameter of about 6 mm. in the body of the penis; it is dilated at its commencement to form the *intrabulbar fossa*, and again within the glans penis, where it forms the *fossa terminalis* (fossa navicularis). The enlargement of the intrabulbar fossa affects the floor and sidewalls but not the roof of the urethra. The bulbo-urethral glands open into the spongy portion of the urethra about 2·5 cm. below the perineal membrane.

The *external urethral orifice* is the narrowest part of the urethra: it is a sagittal slit, about 6 mm. long, bounded on each side by a small labium.

The lining membrane of the urethra, except in the most anterior part of the tube, presents the orifices of numerous small mucous glands and follicles situated in the submucous tissue, and named the *urethral glands*. Besides these there are a number of small pit-like recesses, or *lacunæ*, of varying sizes; the orifices of these are directed forwards, and may intercept the point of a catheter in its passage along the canal. One lacuna, larger than the rest, is situated on the upper wall of the fossa terminalis; it is called *lacuna magna*.

Structure.—The urethra is composed of mucous membrane, supported by a submucous tissue which connects it with the various structures through which it passes.

The *mucous membrane* of the urethra is continuous internally with that of the bladder, and externally with the skin covering the glans penis; it is prolonged into the ducts of the urethral, bulbo-urethral and prostatic glands; and into the vasa deferentia and vesiculæ seminales, through the ejaculatory ducts. In the spongy and membranous portions of the urethra it is aranged in longitudinal folds when the tube is empty. Small papillæ are found upon it, near the external urethral orifice; its epithelial lining is of the transitional variety as far as the orifice of the ejaculatory duct; thereafter it is of the columnar variety, usually two or three layers deep, except near the external urethral orifice, where it is squamous and stratified.

The *submucous tissue* consists of a vascular erectile layer; outside this there is a layer of unstriped muscular fibres, arranged into an inner longitudinal and an outer circular layer and best marked in the prostatic and membranous portions.

The lymph vessels of the urethra are described on p. 873.

Applied Anatomy.—The urethra may be ruptured by the patient falling astride of any hard substance and striking his perineum, so that the urethra is crushed against the pubic arch. Bleeding will at once take place from the urethra, and this, together with the bruising in the perineum and the history of the accident, will point to the nature of the injury. Rupture of the urethra is due in other cases to the perforation of a peri-urethral abscess. Extravasation of urine most frequently takes place into the perineum superficial to the perineal membrane, but deep to the membranous layer of the superficial fascia. Both these layers of fascia are attached firmly to the ischiopubic rami. It is clear, therefore, that when extravasation of fluid takes place between them, it cannot pass backwards, because the two layers are continuous with each other around the Transversi perinæi superficiales; it cannot extend laterally, on account of the connexion of these layers with the rami of the pubis and ischium; it cannot find its way into the pelvis, because the opening into this cavity is closed by the perineal membrane, and, therefore, so long as this layer remains intact, the only direction in which the fluid can make its way is forwards into the areolar tissue of the scrotum and the penis, and thence on to the anterior wall of the abdomen. When the pelvis is crushed the urethra may be ruptured above the perineal membrane; the extravasation of urine then takes place into the extra-peritoneal tissue of the pelvis.

The anatomy of the urethra is of considerable importance in connexion with the passage of instruments into the bladder. The urethra is capable of great dilation, so that, excepting through the external urethral orifice, an instrument corresponding to 18 English gauge (29 French) can usually be passed without damage. The external orifice of the urethra is not so dilatable, and therefore may require slitting. In passing catheters, especially fine ones, the point of the instrument should be kept as far as possible along the upper wall of the canal after the fossa terminalis has been traversed, as otherwise it is very liable to enter one of the lacunæ.

THE FEMALE URETHRA (fig. 1227)

The female urethra is about 4 cm. long and 6 mm. in diameter. It begins at the internal urethral orifice of the bladder, and runs downwards and forwards behind the symphysis pubis, imbedded in the anterior wall of the vagina. It perforates the perineal membrane and ends at the external urethral orifice, an anteroposterior slit with rather prominent margins, which is situated directly in front of the opening of the vagina and about 2·5 cm. behind the glans clitoridis. Except during the passage of fluid the anterior and posterior walls of the urethra are in apposition, and the lining membrane is thrown into longitudinal folds, one of which, placed on the posterior wall of the canal, is termed the *urethral crest*. Many small *urethral glands* and minute pit-like recesses or *lacunæ* open into the urethra. Near the lower end of the urethra there are some small glands, which are considered to be the homologues of the prostatic glands of the male; on each side they are grouped together and open into a duct, named the *ductus paraurethralis*, which runs down in the submucous tissue, and ends in a small aperture on the lateral margin of the external urethral orifice.

Structure.—The urethra consists of three coats: muscular, erectile and mucous.

The *muscular coat* is continuous with that of the bladder; it extends the whole length of the tube, and consists of inner longitudinal and outer circular fibres. In addition to this, above the perineal membrane, the female urethra is surrounded by the Sphincter urethræ, as in the male.

A thin layer of *spongy erectile tissue*, containing a plexus of large veins, intermixed with bundles of unstriped muscular fibres, lies immediately beneath the mucous coat.

The *mucous coat* is pale; it is continuous externally with that of the vulva, and internally with that of the bladder. It is lined by stratified squamous epithelium, which becomes transitional near the bladder. Its external orifice is surrounded by a few mucous follicles.

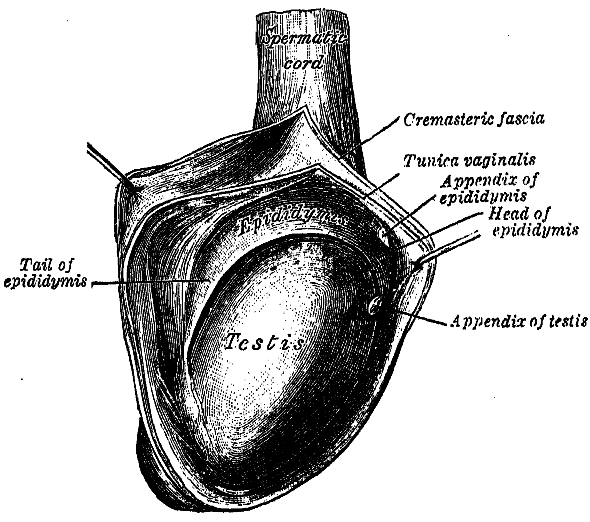
THE MALE GENITAL ORGANS

The male genital organs include the *testes* and *epididymides*, the *vasa deferentia*, the *vesiculæ seminales*, the *ejaculatory ducts* and the *penis*, together with the following accessory structures, viz. the *prostate* and the *bulbo-urethral glands*.

The Testes

The **testes**, the reproductive glands in the male, are suspended in the scrotum by the spermatic cords, the left testis hanging somewhat lower than its fellow. The average dimensions of the testis are from 4 cm. to 5 cm. in length, 2·5 cm. in breadth, and 3 cm. in the anteroposterior diameter; its weight varies from 10·5 gm. to 14 gm. Each testis is of an oval form (fig. 1231), compressed

Fig. 1231.—The right testis. Exposed by laying open the tunica vaginalis.



laterally, and has an oblique position in the scrotum; the upper extremity is directed forwards and a little laterally; the lower, backwards and a little medially. The anterior border is convex, and looks forwards and downwards; the posterior border, nearly straight, looks backwards and upwards; to it the spermatic cord is attached.

The anterior border, the medial and lateral surfaces, and the extremities of the testis, are convex, free, smooth, and invested by the visceral layer of the tunica vaginalis (p. 1381). The posterior border receives only a partial investment from that membrane. The epididymis lies along the lateral part of the posterior border.

The **epididymis** consists essentially of a tortuous canal which forms the first part of the efferent duct of the testis. This canal is folded on itself and tightly packed into the form of a long, narrow, flattened body attached to the lateral part of the posterior border of the testis. It consists of a central portion, or *body*; an upper enlarged end, or *head*; and a lower pointed end, or *tail*. The head is intimately connected with the upper end of the testis by means of the efferent ductules of the gland; the tail is connected with the lower end by cellular tissue and a reflection of the tunica vaginalis. The lateral surfaces of the head and tail of the epididymis are free and covered by the tunica vaginalis;

the body is also invested by it, except at its posterior border. A recess of the tunica vaginalis, named the *sinus of the epididymis*, lies between the body of the epididymis and the lateral surface of the testis.

The *appendages of the testis and epididymis*.—On the upper extremity of the testis, just beneath the head of the epididymis, there is a minute, oval, sessile body, termed the *appendix of the testis*; it is the remnant of the upper end of the paramesonephric duct. On the head of the epididymis there is a small, stalked appendage (sometimes duplicated); it is named the *appendix of the epididymis*, and is usually considered to be a derivative of the mesonephros.

The testis is invested by three tunics: the tunica vaginalis, tunica albuginea and tunica vasculosa.

The **tunica vaginalis** is the lower portion of the processus vaginalis of the peritoneum, which, in the fœtus, preceded the descent of the testis from the abdomen into the scrotum (p. 192). After the testis has reached the scrotum the upper part of the processus vaginalis, viz. from the deep inguinal ring to within a short distance of the testis, contracts and undergoes obliteration. The lower portion remains as a closed sac, which invests the surface of the testis, and is reflected on to the internal surface of the scrotum; hence it may be described as consisting of a visceral and a parietal layer.

The *visceral layer* covers the lateral and medial surfaces and the anterior border of the testis, but leaves the posterior border uncovered. At the medial side of the posterior border it is reflected forwards to become continuous with the parietal layer (fig. 1237). At the lateral side of the posterior border it is reflected on to the medial aspect of the epididymis, lining the sinus of the epididymis, and then over its lateral aspect as far as its posterior border (fig. 1237), where it is reflected forwards to become continuous with the parietal layer. The continuity between the visceral and parietal layers is established also at the upper and lower poles of the testis, but at the upper pole the visceral layer covers the upper surface of the head of the epididymis before being reflected.

The *parietal layer* is more extensive than the visceral; it reaches below the testis and extends upwards for some distance in front and on the medial side of the spermatic cord. The inner surface of the tunica vaginalis is smooth, and covered with a layer of endothelial cells. The potential space between the visceral and parietal layers constitutes the cavity of the tunica vaginalis.

The obliterated portion of the processus vaginalis may frequently be seen as a fibrous thread in the anterior part of the spermatic cord; sometimes this thread may be traced from the upper end of the inguinal canal, where it is connected with the peritoneum, down to the tunica vaginalis; sometimes it is lost in the spermatic cord. In some instances the upper part of the processus vaginalis is not obliterated, and the peritoneal cavity then communicates with the tunica vaginalis; in others the upper part of the processus vaginalis may persist but its lower end is shut off from the tunica vaginalis.

The **tunica albuginea** forms a fibrous covering for the testis. It is a dense membrane, of a bluish-white colour, composed of interlacing bundles of white fibrous tissue. It is covered with the visceral layer of the tunica vaginalis, except at the head and tail of the epididymis, and along the posterior border of the testis, where the testicular vessels and nerves enter the gland. It is applied to the tunica vasculosa, and, at the posterior border of the testis, is projected into the interior of the gland, forming an incomplete, vertical septum, called the *mediastinum testis*.

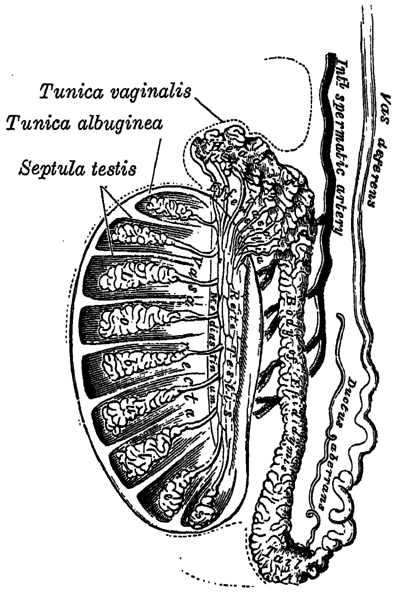
The *mediastinum testis* extends from the upper to near the lower end of the gland, and is wider above than below. From its front and sides numerous imperfect septa [*septa testis*] are given off and radiate towards the surface of the testis, where they are attached to the deep aspect of the tunica albuginea. They divide the testis incompletely into a number of cone-shaped lobes.

The bases of the lobes are at the surface of the testis, and their apices converge to the mediastinum. The mediastinum supports the vessels and ducts of the testis in their passage to and from the substance of the gland.

The **tunica vasculosa** is the vascular layer of the testis, consisting of a plexus of blood-vessels held together by delicate areolar tissue. It lines the tunica albuginea and clothes the septa, and therefore forms an investment to all the lobes of the testis.

Structure.—The serous covering of the testis consists of a layer of flattened endothelial cells similar to those which line the peritoneal cavity. The glandular structure of the testis consists of the lobes of the testis (fig. 1232). Their number, in a single testis, is estimated by Berres at 250, and by Krause at 400. They differ in size according to their position, those in the middle of the testis being larger and longer. Each lobe consists of from one to three, or more, minute convoluted tubes, termed the convoluted seminiferous tubules [*tubuli seminiferi convoluti*]. When the tubules have been unravelled by careful dissection under water, they are seen to commence either by free blind ends or by anastomotic loops. They are supported by loose connective tissue which contains here and there groups of *interstitial cells* (fig. 1233) containing yellow pigment granules. The total number of tubules is estimated by Lauth at 840, and the average length of each is 70 cm. to 80 cm. Their diameter varies from 0·12 mm. to 0·3 mm. The tubules are pale in colour in early life, but in old age they contain much fatty matter and acquire a deep yellow tinge. Each tubule (fig. 1233) consists of a basement-layer formed of laminated connective tissue containing numerous elastic fibres, with flattened cells between the layers, and covered externally with a layer of flattened epithelioid cells. Within the basement-membrane epithelial cells are arranged in three irregular layers. 1. An outer layer of cubical cells, with small nuclei; some of these enlarge to become *spermatogonia*. The nuclei of some of the spermatogonia may be seen to be in process of indirect division (see p. 2), and in consequence of this, daughter cells are formed which constitute the second zone. 2. Larger polyhedral cells, with clear nuclei, arranged in two or three layers; these are the *intermediate cells* or *spermatocytes*. Most of these cells are in a condition of indirect division, and the cells which result from this division form those of the next layer. 3. The third layer of cells consists of the *spermatids*, each of which becomes a *spermatozoon*. The spermatids are small polyhedral cells, the nucleus of each containing half the usual number of chromosomes. The changes which occur during the conversion of the spermatids into spermatozoa are described and illustrated on p. 49. In addition to these three layers of cells, others, termed the *supporting cells*, or *cells of Sertoli*, are seen. They are elongated and columnar, and project inwards from the basement-membrane towards the lumen of the tube. As development of the spermatozoa proceeds, the latter group themselves upon the inner extremities of the supporting cells. Ultimately the spermatozoa are liberated and set free. The structure of the spermatozoa is described on p. 48.

FIG. 1232.—A vertical section through the testis, to show the arrangement of the ducts. Diagrammatic.



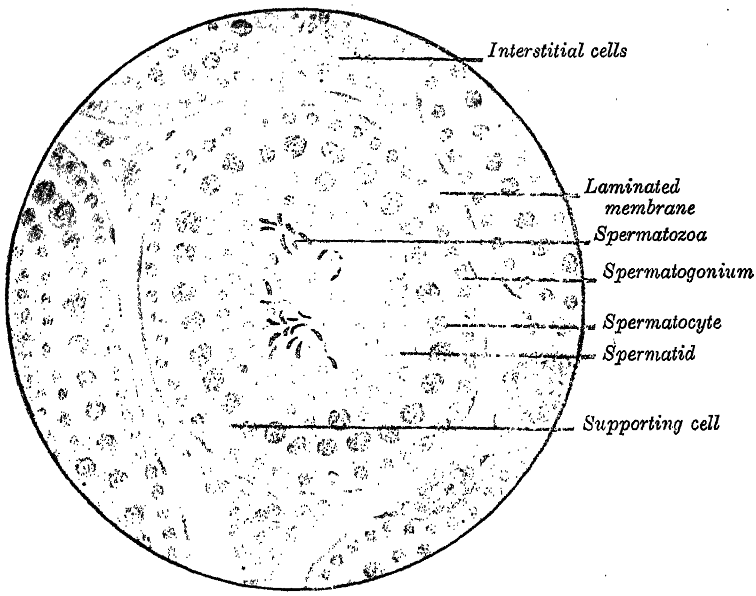
In the apices of the lobes, the tubules become less convoluted, assume a nearly straight course, and unite at acute angles to form from twenty to thirty larger straight ducts, of about 0·5 mm. in diameter, called tubuli seminiferi recti (fig. 1232).

The straight seminiferous tubules [*tubuli seminiferi recti*] enter the fibrous tissue of the mediastinum, and pass upwards and backwards, forming, in their ascent, a close network of anastomosing tubes which are merely channels in the fibrous stroma, lined by flattened epithelium, and having no proper walls; this network is named the *rete testis*. At the upper end of the mediastinum these channels terminate in from twelve to twenty ducts, termed the *efferent ductules*; they perforate the tunica albuginea, and carry the seminal fluid from the testis to the epididymis. Their course is at first straight; then they become enlarged and exceedingly convoluted, and form a series of conical masses, known as the *lobules of the epididymis*, which together constitute the head of the epididymis. Each lobule consists of a single convoluted duct, from 15 cm. to 20 cm. in length. Opposite the bases of the lobules the ducts open into a single canal, which constitutes, by its complex convolutions, the body and tail of the epididymis. When the convolutions are unravelled, this tube measures upwards of 6 metres in length; it increases in diameter and thickness as it approaches the tail of the epididymis where it becomes the vas deferens. The convolutions are held together by fine areolar tissue, and by bands of fibrous tissue.

The efferent ductules and the canal of the epididymis have walls of considerable thickness, on account of the presence in them of muscular tissue, which is principally arranged in a circular manner. These tubes are lined by ciliated columnar epithelium (fig. 1234).

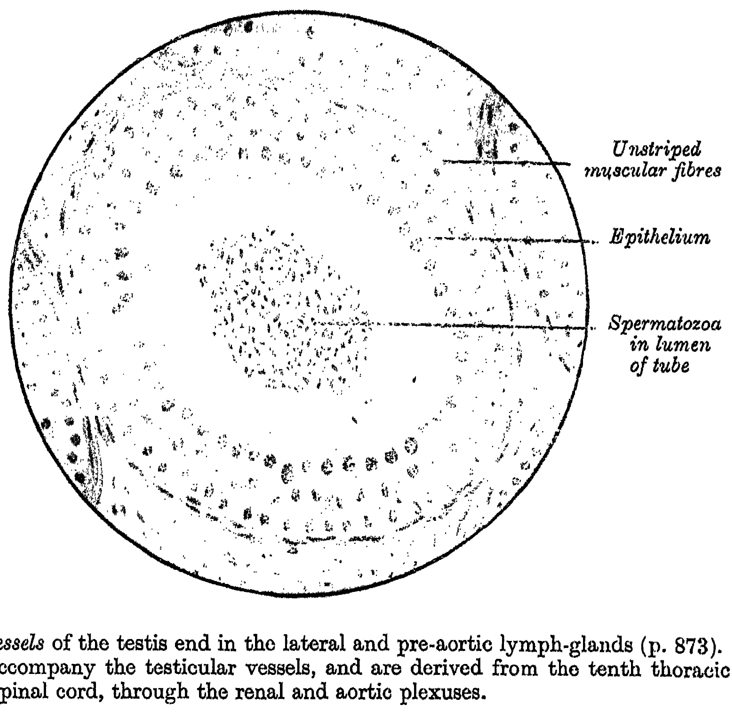
Vessels and Nerves.—The *testicular artery* is a branch of the abdominal aorta. It divides into several branches, some of which ramify in the tunica vasculosa, while others traverse the mediastinum testis and, after dividing on the septa testis, supply the semini-

FIG. 1233.—A transverse section through a part of a human testis. Stained with hæmatoxylin and eosin. ×350.



ferous tubules. Twigs are also given to the epididymis, and anastomose with the artery of the vas deferens. The *veins* emerge from the back of the testis and, after receiving tributaries from the epididymis, unite to form the pampiniform plexus (p. 839).

FIG. 1234.—A transverse section through the tube of the adult human epididymis. Stained with hæmatoxylin and eosin. ×350.



The *lymph vessels* of the testis end in the lateral and pre-aortic lymph-glands (p. 873).

The *nerves* accompany the testicular vessels, and are derived from the tenth thoracic segment of the spinal cord, through the renal and aortic plexuses.

Applied Anatomy.—At an early period of fœtal life the testes are placed in the posterior part of the abdominal cavity. Their descent into the scrotum is described on p. 192. The descent of the testis may be arrested. It may be retained in the abdomen; or it may be arrested at the deep inguinal ring, or in the inguinal canal; or it may just pass out of the superficial inguinal ring without finding its way to the bottom of the scrotum. When retained in the abdomen it gives rise to no signs or symptoms, other than the absence of the testis from the scrotum. When it is retained in the inguinal canal it is subjected to pressure and may become inflamed and painful. The retained testis is probably useless sexually; so that a man in whom both testes are retained (*anorchism*) is sterile, though he may not be impotent. The absence of one testis is termed *monorchism*. When a testis is retained in the inguinal canal it is often complicated with a congenital hernia, the processus vaginalis of the peritoneum not being obliterated. The testis may descend through the inguinal canal, but may miss the scrotum and assume some abnormal position (p. 192).

The testis may be inverted within the scrotum so that its posterior or attached border is directed forwards and the tunica vaginalis is situated behind. Should a hydrocele occur, and tapping be resorted to, the trocar may be thrust into the testis, unless care be taken beforehand to ascertain the position of the gland.

A number of instances of torsion of the spermatic cord, resulting in acute strangulation of the testis, have been recorded. In some it has been attributed to a strain or twist, and in several patients the condition has been associated with a late descent of the organ. In consequence of the torsion the circulation is partly arrested and the organ swells and becomes acutely painful, and the condition may be accompanied with shock and vomiting.

Fluid collections of a serous character are frequently found in the scrotum. To these the term *hydrocele* is applied. The most common form is the ordinary *vaginal hydrocele*, in which the fluid is contained in the sac of the tunica vaginalis. In another form, the congenital hydrocele, the fluid is in the sac of the tunica vaginalis, but this sac communicates with the general peritoneal cavity owing to the non-obliteration of the upper part of the processus vaginalis. A third variety, known as an *infantile hydrocele*, occurs in those cases where the processus vaginalis is obliterated only at or near the deep inguinal ring. It resembles the vaginal hydrocele, except as regards its shape, the collection of fluid extending up the cord into the inguinal canal. Fourthly, the processus vaginalis may be obliterated both at the deep inguinal ring and above the epididymis, leaving a central unobliterated portion, which may become distended with fluid, giving rise to a condition known as *encysted hydrocele of the cord*.

Encysted hydrocele of the epididymis, or *spermatocele*, is the name given to a cyst found in connexion with the head of the epididymis. Among its contents are found a varying number of spermatozoa, and it is probably a retention cyst of one of the tubules.

The Vas Deferens

The **vas deferens** (ductus deferens) is the continuation of the canal of the epididymis (fig. 1232). Commencing at the lower part of the tail of the epididymis, it is at first very tortuous, but gradually becoming straighter it ascends along the posterior border of the testis and the medial side of the epididymis. From the upper pole of the testis it runs upwards in the posterior part of the spermatic cord, and traverses the inguinal canal to the deep inguinal ring. Here it separates from the other structures of the spermatic cord, curves round the lateral side of the inferior epigastric artery, and ascends for about 2·5 cm. in front of the external iliac artery. It is next directed backwards and slightly downwards, and, crossing the external iliac vessels obliquely, enters the pelvic cavity, where it is continued backwards between the peritoneal membrane and the lateral wall of the pelvis, and on the medial side of the obliterated umbilical artery, the obturator nerve and vessels, and the vesical vessels (fig. 1223). It then crosses in front of the ureter (fig. 1235), and, reaching the medial side of this tube, bends at an acute angle, and runs medially and slightly forwards between the base of the bladder and the upper end of the seminal vesicle. Reaching the medial side of the seminal vesicle, it is directed downwards and medially in contact with it, and gradually approaches the opposite vas. Here it lies between the base of the bladder and the rectum, from which it is separated by the rectovesical fascia. Lastly, it passes downwards to the base of the prostate, and is joined at an acute angle by the duct of the seminal vesicle to form the ejaculatory duct (fig. 1236), which traverses the prostate behind its median lobe and opens into the prostatic portion of the urethra, close to the orifice of the prostatic utricle. Owing to the thickness of its wall relative to the small size of its lumen, the vas deferens feels hard and cord-like when grasped by the finger and thumb. Its canal in the greater part of its extent is of ex-

tremely small calibre, but at the base of the bladder it becomes dilated and tortuous, and this portion is termed the *ampulla* ; its terminal portion, which joins the duct of the seminal vesicle, is again greatly diminished in calibre (fig. 1236).

Ductuli aberrantes.—A long narrow tube, termed the *ductulus aberrans inferior*, is frequently found connected with the lower part of the canal of the epididymis, or with the commencement of the vas deferens. Its length, when it is uncoiled, varies from 5 cm. to 35 cm., and it may be dilated towards its blind extremity, or may be of uniform diameter throughout. Its structure is similar to that of the vas deferens. Occasionally it is found unconnected with the epididymis. A second tube, termed the *ductulus aberrans superior*, occurs in the head of the epididymis, and is connected with the rete testis.

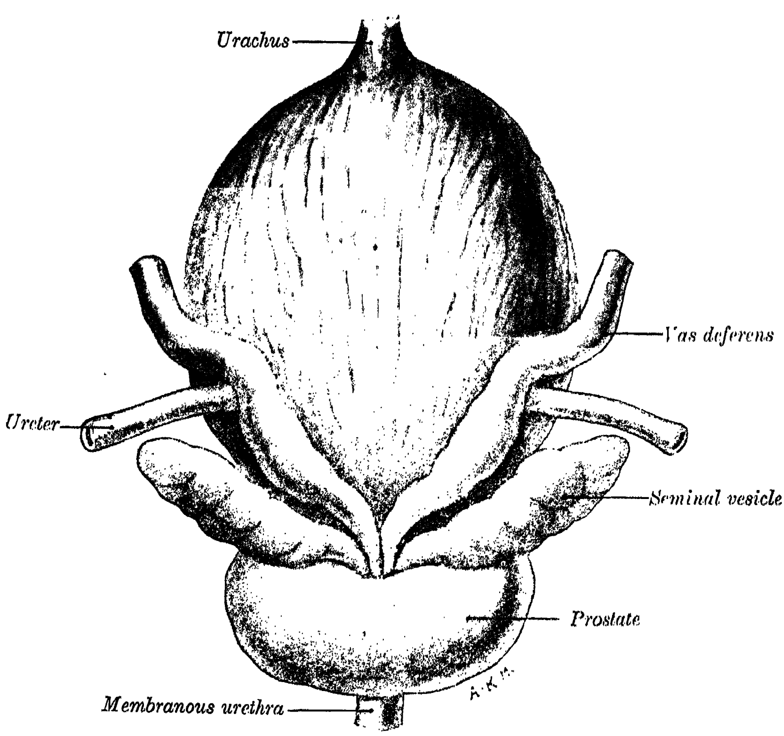
Paradidymis.—This term is applied to a small collection of convoluted tubules, situated in front of the lower part of the spermatic cord above the head of the epididymis. These tubes are lined with ciliated columnar epithelium, and probably represent the remains of a part of the mesonephros (p. 185).

Structure.—The vas deferens consists of three coats: (1) an external or areolar coat; (2) a muscular coat, which in the greater part of the tube consists of two layers of unstriped muscular fibres: an outer, longitudinal in direction, and an inner, circular; but at the commencement of the vas there is a third layer, consisting of longitudinal fibres, and placed between the circular stratum and the mucous membrane; (3) an internal, or mucous coat, which is pale, and arranged in longitudinal folds. The mucous coat is lined with columnar epithelium, which is non-ciliated throughout the greater part of the tube; a variable portion of the testicular end of the tube is lined with two strata of columnar cells, those of the superficial layer being ciliated.

The Seminal Vesicles and Ejaculatory Ducts

The **seminal vesicles** (fig. 1235) are two sacculated pouches, placed between the base of the bladder and the rectum. Each vesicle is about 5 cm.

Fig. 1235.—The bladder, seminal vesicles, etc. Viewed from above and behind.

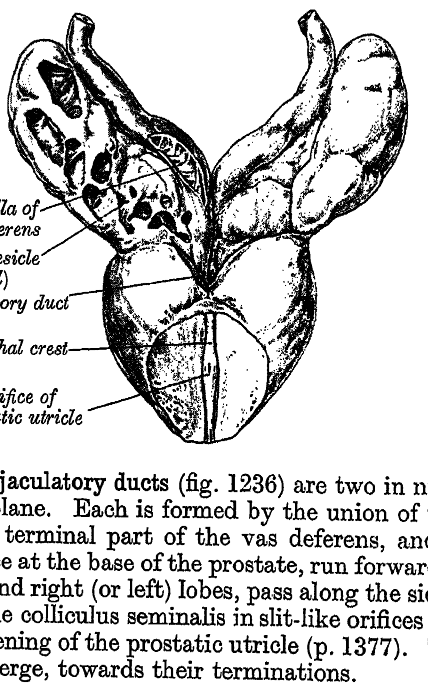


long, and is somewhat pyramidal in form, the broad end being directed backwards, upwards and laterally. It consists of a tube, coiled upon itself, and giving off several irregular diverticula (fig. 1236); the separate coils, as well as the diverticula, are connected together by fibrous tissue. When uncoiled, the tube is about the diameter of a quill, and varies in length from 10 cm. to 15 cm.;

it ends above in a cul-de-sac; its lower extremity becomes constricted into a narrow straight duct, which joins with the corresponding vas deferens to form the ejaculatory duct. The *anterior surface* is in contact with the base of the bladder, extending from near the termination of the ureter to the base of the prostate. The *posterior surface* rests upon the rectum, from which it is separated by the rectovesical fascia. The vesicles diverge from each other above, and are in relation with the vasa deferentia and the terminations of the ureters, and are partly covered with peritoneum; each is enveloped in a dense, fibromuscular sheath. Along the medial margin of the vesicle runs the ampulla of the vas deferens. Lateral to the vesicle, the veins of the prostatic venous (pudendal) plexus pass backwards to join the internal iliac vein.

Structure.—The seminal vesicles are composed of three coats: an *external* or *areolar coat*; a *middle* or *muscular coat*, thinner than that of the vas deferens and arranged in two layers, an outer longitudinal and an inner circular; an *internal* or *mucous coat*, which is pale, of a whitish-brown colour, and presents a delicate, reticular structure. The epithelium is columnar, and in the diverticula goblet-cells are present, the secretion of which forms a large part of the seminal fluid.

FIG. 1236.—The seminal vesicles, the terminal portions of the vasa deferentia, and the prostate, exposed from in front. The anterior walls of the right seminal vesicle and of the ampulla of the right vas deferens have been removed, and the prostatic part of the urethra has been opened from in front by the removal of a portion of the prostate.



Vessels and Nerves.—The *arteries* supplying the seminal vesicles are derived from the inferior vesical, and the middle rectal arteries. The *veins* and *lymph vessels* accompany the arteries. The *nerves* are derived from the pelvic plexuses.

Applied Anatomy.—The seminal vesicles are often the seat of the disease in cases of tuberculosis of the genito-urinary tract, and should always be examined from the rectum, in cases where the testes are involved. They also become affected in chronic posterior urethritis of gonorrhœal origin. An abscess of the seminal vesicle may rupture into the peritoneal cavity and cause fatal peritonitis.

The ejaculatory ducts (fig. 1236) are two in number, one on each side of the median plane. Each is formed by the union of the duct of the seminal vesicle with the terminal part of the vas deferens, and is nearly 2 cm. long. They commence at the base of the prostate, run forwards and downwards between the median and right (or left) lobes, pass along the sides of the prostatic utricle, and end on the colliculus seminalis in slit-like orifices on, or just within, the margins of the opening of the prostatic utricle (p. 1377). The ducts diminish in size, and also converge, towards their terminations.

Structure.—The coats of the ejaculatory ducts are extremely thin. They are: an *outer fibrous layer*, which is almost entirely lost after the entrance of the ducts into the prostate; a *layer of muscular fibres*, consisting of a thin outer circular, and an inner longitudinal layer; and *mucous membrane*.

The Spermatic Cord and its Coverings

When the testis descends through the abdominal wall into the scrotum, it drags its vessels and nerves and the vas deferens with it. These structures meet at the deep inguinal ring and together form the *spermatic cord*, which suspends the testis in the scrotum, and extends from the deep inguinal ring to the posterior border of the testis; the left spermatic cord is a little longer than the right.

The spermatic cord traverses the inguinal canal (p. 571) and in so doing acquires coverings from the different layers which form the abdominal wall These coverings extend downwards into the wall of the scrotum and are named

from within outwards, the internal spermatic, cremasteric and external spermatic fasciæ.

The *internal spermatic fascia* is a thin layer which loosely invests the spermatic cord, and is derived from the transversalis fascia (p. 571).

The *cremasteric fascia* consists of a number of muscular fasciculi, united to one another by areolar tissue ; the muscular fasciculi constitute the Cremaster and are continuous with the Obliquus internus abdominis (p. 566).

The *external spermatic fascia* is a thin fibrous membrane continuous above with the aponeurosis of the Obliquus externus abdominis, and prolonged downwards from the crura of the superficial ring (p. 563).

Structure of the spermatic cord.—The spermatic cord is composed of arteries, veins, lymph vessels, nerves, and the vas deferens, connected together by areolar tissue.

The *arteries* of the spermatic cord are : the testicular artery, the artery to the cremaster and the artery of the vas deferens.

The *testicular artery*, a branch of the abdominal aorta (p. 771), escapes from the abdominal cavity at the deep inguinal ring, and accompanies the other constituents of the spermatic cord along the inguinal canal and through the superficial inguinal ring into the scrotum. It then descends to the testis, and, becoming tortuous, divides into several branches, two or three of which accompany the vas deferens and supply the epididymis, anastomosing with the artery of the vas deferens ; the others supply the substance of the testis.

The *artery to the cremaster* (external spermatic artery) is a branch of the inferior epigastric artery (p. 784). It supplies the coverings of the spermatic cord, and anastomoses with the testicular artery.

The *artery of the vas deferens*, a branch of either the inferior or the superior vesical artery (p. 777), is a long slender vessel which accompanies the vas deferens, ramifying upon its coats, and anastomosing with the testicular artery near the testis. Near its origin it sends a small branch downwards to supply the ampulla of the vas deferens and the seminal vesicle.

The *testicular veins* emerge from the back of the testis, and receive tributaries from the epididymis : they unite and form a convoluted plexus, named the *pampiniform plexus*, which constitutes the chief mass of the cord ; the vessels composing this plexus are very numerous, and ascend in front of the vas deferens ; below the superficial inguinal ring they unite to form three or four veins which pass along the inguinal canal, and, entering the abdomen through the deep inguinal ring, coalesce to form two veins. These again unite to form a single vein, which opens on the right side into the inferior vena cava, at an acute angle, and on the left side into the left renal vein, at a right angle.

The *lymph vessels* of the testis are described on p. 873.

The *nerves* are (1) the genital branch of the genitofemoral nerve (p. 1113), and (2) the testicular plexus of the sympathetic (p. 1151), joined by filaments from the pelvic plexus which accompany the artery of the vas deferens.

The Scrotum

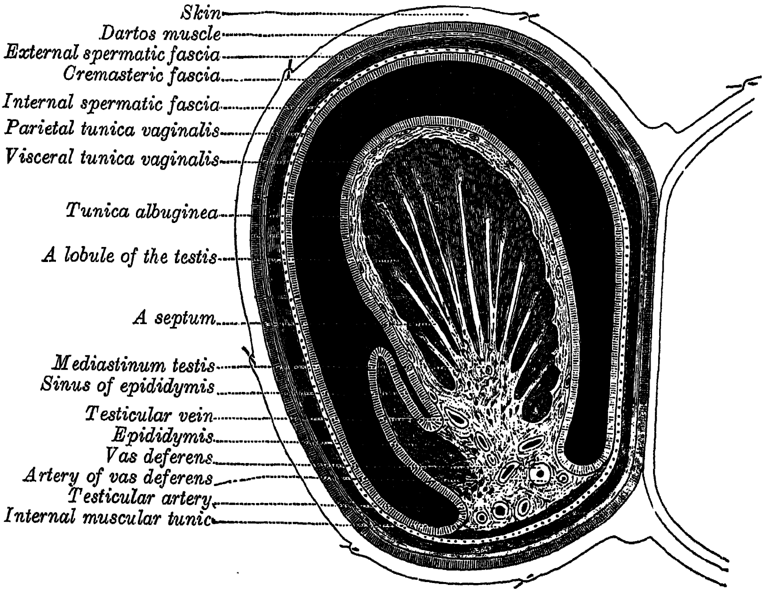
The *scrotum* is a cutaneous pouch containing the testes and the lower parts of the spermatic cords, and placed below the pubic symphysis in front of the upper parts of the thighs. It is divided on its surface into a right and a left portion by a ridge, or *raphe*, which is continued forwards to the under surface of the penis, and backwards along the middle line of the perineum to the anus ; the left portion hangs lower than the right, in correspondence with the greater length of the left spermatic cord. The external appearance varies under different circumstances : thus, under the influence of warmth, and in old and debilitated persons, the scrotum is elongated and flaccid ; but, under the influence of cold, and in the young and robust, it is short, corrugated, and closely applied to the testes. It consists of the skin and the dartos muscle, together with the external spermatic, cremasteric and internal spermatic fasciæ, already described in connexion with the spermatic cord. The inner surface of the internal spermatic fascia is in contact with the layer of the tunica vaginalis (fig. 1237).

The *skin* is very thin, of a brownish colour, and generally thrown into folds or rugæ. It is beset with thinly scattered, crisp hairs, the roots of which are visible through the skin ; it is provided with sebaceous follicles, the secretion of which has a peculiar odour.

The *dartos muscle* is a thin layer of non-striped muscular fibres, continuous around the base of the scrotum, with the superficial fascia of the groin and of the perineum. It sends inwards a septum, which connects the raphe to the under surface of the root of the penis, and divides the scrotal pouch into two

cavities for the testes. The dartos muscle is closely united to the skin, but is connected with the subjacent parts by delicate areolar tissue, upon which it glides with the greatest facility.

Fig. 1237.—A transverse section through the left half of the scrotum and the left testis. The sac of the tunica vaginalis is represented in a distended condition. Diagrammatic. (Delépine.)



Vessels and Nerves.—The *arteries* supplying the scrotum are: the external pudendal branches of the femoral artery (p. 789), the scrotal branches of the internal pudendal artery (p. 779), and the cremasteric branch from the inferior epigastric artery (p. 784). The *veins* follow the course of the corresponding arteries. The *lymph vessels* end in the inguinal lymph-glands (p. 862). The *nerves* are the ilio-inguinal and genital branch of the genitofemoral (p. 1113), the two scrotal branches of the perineal nerve (p. 1128), and the perineal branch of the posterior femoral cutaneous nerve (p. 1122).

Applied Anatomy.—The scrotum forms an admirable covering for the protection of the testes. These bodies, lying suspended and loose in the cavity of the scrotum and surrounded by serous membrane, are capable of great mobility, and can therefore easily slip about within the scrotum, and thus avoid injuries from blows or squeezes. The skin of the scrotum is very elastic and capable of great distension, and on account of the looseness and amount of subcutaneous tissue, the scrotum becomes greatly enlarged in cases of œdema, to which this part is especially liable as a result of its dependent position.

The Penis

The penis is a pendulous organ suspended from the front and sides of the pubic arch and containing the greater part of the urethra. In the flaccid condition it is cylindrical in shape, but when erect it assumes the form of a triangular prism with rounded angles, one side of the prism forming the dorsum of the penis. It is composed of three cylindrical masses of erectile tissue bound together by fibrous tissue and covered with skin. Two of the masses are placed side by side, and are known as the *corpora cavernosa penis*; the third, median in position and beneath the other two, is traversed by the spongy part of the urethra, and is termed the *corpus spongiosum penis* (corpus cavernosum urethræ) (figs. 1238, 1239).

The **corpora cavernosa penis** form the greater part of the substance of the penis. Throughout the anterior three-fourths of their extent they lie in apposition with each other, separated only by the septum of the penis (fig. 1239); behind, they diverge in the form of two tapering processes, which are known as the *crura of the penis*, and are firmly connected to the rami of

the pubic arch. Traced from behind forwards each crus begins as a blunt-pointed process in front of the tuberosity of the ischium. Just before it meets its fellow it presents a slight enlargement. Beyond this point the crus undergoes a constriction and merges into the corpus cavernosum proper, which retains a uniform diameter to its anterior end. Each corpus cavernosum penis ends abruptly in a round extremity a short distance from the end of the penis.

The corpora cavernosa penis are surrounded by a strong, fibrous envelope consisting of superficial and deep fibres. The superficial fibres are longitudinal in direction, and form a single tube which encloses both corpora; the deep fibres are arranged circularly round each corpus, and form by their junction in the median plane the *septum of the penis*. This septum is thick and complete behind, but is imperfect in front, where it consists of a series of bands arranged like the teeth of a comb; it is therefore sometimes named the *septum pectiniforme*.

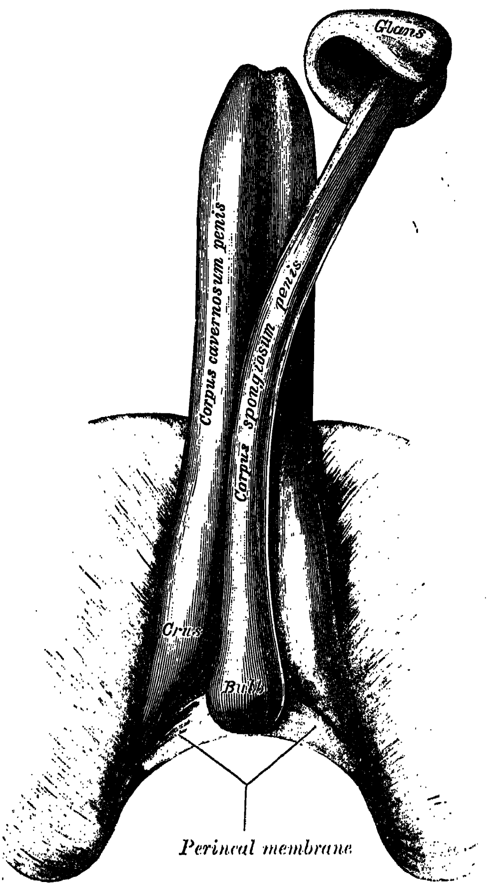


FIG. 1238.—The constituent cavernous cylinders of the penis. The glans penis and the anterior part of the corpus spongiosum penis are detached from the corpora cavernosa penis and turned to one side.

The **corpus spongiosum penis** (corpus cavernosum urethrae) contains the spongy part of the urethra. Behind, it is expanded to form the bulb of the penis, and lies in apposition with the perineal membrane, from which it receives a fibrous investment. The urethra enters the bulb nearer to the upper than to the lower surface. On the lower surface of the bulb there is a median sulcus, from which a thin fibrous septum projects into the substance of the bulb and divides it imperfectly into two lateral lobes or *hemispheres*.

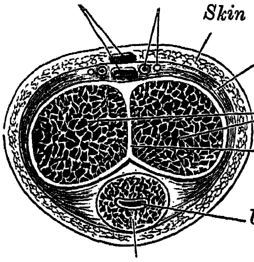
The portion of the corpus spongiosum penis in front of the bulb lies in a groove on the under surface of the conjoined corpora cavernosa penis. It is cylindrical in form and tapers slightly from behind forwards. Its anterior end suddenly expands to form an obtuse cone, named the *glans penis*.

For descriptive purposes it is convenient to divide the penis into three regions: the root, the body, and the extremity.

The **root** of the penis is triradiate in form, consisting of the diverging crura, one on each side, and the bulb of the penis in the median plane (fig. 1238). Each crus is covered with the Ischio-cavernosus, while the bulb is surrounded by the Bulbo-spongiosus. The root of the penis lies in the perineum between the perineal membrane and the membranous layer of the superficial fascia. In addition to being attached to the fasciæ and the pubic rami, it is bound to the front of the symphysis by the fundiform and suspensory ligaments. The *fundiform ligament* springs from the lower part of the linea alba and from the adjoining parts of the sheaths of the Recti abdominis; it splits into two fasciculi which pass one on each side of the penis and unite below with the septum of the scrotum. The *suspensory ligament* is triangular in shape; it is attached above to the symphysis pubis; below, it blends with the fibrous envelope of the corpora cavernosa penis.

The **body** of the penis extends from the root to the anterior end of the corpora cavernosa penis. In the body the corpora cavernosa are intimately bound to each other; a shallow groove which marks their junction on the upper surface lodges the deep dorsal vein of the penis, while a deeper and wider groove between them on the under surface contains the corpus spongiosum penis. The body is ensheathed by fascia, which is continuous above with the membranous layer of the superficial fascia of the abdominal wall above, and of the perineum below.

FIG. 1239.—A transverse section through the penis.



The **extremity** is formed by the glans penis, the expanded anterior end of the corpus spongiosum penis. The glans penis is somewhat conical in shape and its concave base covers, and is attached to, the ends of the corpora cavernosa. The projecting margin of its base is named the *corona glandis*, and the constriction behind the latter is known as the *neck of the penis*. The terminal part of the urethra runs through the glans penis, and ends in a sagittal slit on its apex.

The skin covering the penis is remarkable for its thinness, its dark colour, its looseness of connexion with the fibrous envelope of the organ, and the absence of adipose tissue. At the root of the penis it is continuous with the skin over the pubes, scrotum and perineum. At the neck of the penis it is folded upon itself to form the *prepuce* or *foreskin*, which overlaps the glans for a variable distance. The internal layer of the prepuce is confluent along the line of the neck with the thin skin which covers, and adheres firmly to, the glans, and is continuous with the mucous membrane of the urethra at the external urethral orifice. On the under surface of the glans penis a small median fold passes from the deep surface of the prepuce to a point on the glans immediately behind the external urethral orifice; this median fold is named the *frenulum* of the prepuce. The prepuce is separated from the glans penis by a potential sac—the *preputial sac*—which presents two shallow fossæ, one on each side of the frenulum. On the corona of the glans and on the neck of the penis there are numerous small *preputial glands*; these secrete a sebaceous material named the *smegma*, which possesses a very peculiar odour.

Structure of the penis.—From the internal surface of the fibrous envelope of the corpora cavernosa penis, as well as from the sides of the septum, numerous *trabeculæ* arise, and cross the corpora cavernosa in all directions, subdividing them into a number of *cavernous spaces*, and giving the entire structure a spongy appearance (fig. 1239). These trabeculæ consist of white fibrous tissue, elastic fibres and plain muscular fibres, and they contain numerous arteries and nerves. The cavernous spaces are filled with blood, and are lined with a layer of flattened cells similar to the endothelial lining of veins.

The fibrous envelope of the corpus spongiosum penis is thinner, whiter in colour, and more elastic than that of the corpora cavernosa penis. The trabeculæ are more delicate, and the meshes between them are smaller than in the corpora cavernosa penis. The envelope of the corpus spongiosum penis is formed partly of unstriped muscular fibres, and a layer of the same tissue surrounds the canal of the urethra.

Vessels and Nerves.—The arteries bringing the blood to the cavernous spaces are the deep arteries of the penis, and branches from the dorsal arteries of the penis, which perforate the fibrous capsule along the upper surface, especially near the extremity of the organ. On entering the cavernous structure the arteries divide into branches which are supported and enclosed by the trabeculæ. Some of these arteries end in a capillary network, the branches of which open directly into the cavernous spaces; others assume a tendril-like appearance, and form convoluted and somewhat dilated vessels, named *helicine arteries*. They open into the cavernous spaces, and from them small capillary branches go to supply the trabecular structure. They are most abundant in the posterior parts of the corpora cavernosa.

The blood from the cavernous spaces is returned by a series of vessels, some of which emerge from the base of the glans penis and converge on the dorsum of the penis to form the

deep dorsal vein ; others pass out on the upper surface of the corpora cavernosa and join the same vein ; some emerge from the under surface of the corpora cavernosa penis and, receiving branches from the corpus spongiosum penis, wind round the sides of the penis to end in the deep dorsal vein ; but many pass out at the root of the penis and join the prostatic plexus.

The *nerves* are derived from the second, third and fourth sacral nerves, through the pudendal nerve and the pelvic plexuses. On the glans and on the bulb of the penis some filaments of the cutaneous nerves have lamellated corpuscles connected with them, and many of them end in peculiar end-bulbs (p. 1216).

The Prostate

The **prostate** (figs. 1223, 1235) is a firm, partly glandular and partly muscular body, surrounding the commencement of the urethra. It is situated in the pelvic cavity, behind the lower part of the symphysis pubis and the upper part of the pubic arch, and in front of the ampulla of the rectum. It is about the size of a chestnut and somewhat conical in shape, and presents for examination a base, an apex, a posterior, an anterior and two inferolateral surfaces.

The *base* is directed upwards, and, for the greater part of its extent, is directly continuous with the neck of the urinary bladder : the urethra enters it nearer its anterior than its posterior border.

The *apex* is directed downwards and is in contact with the fascia on the deep surfaces of the Sphincter urethræ and the Transversus perinei profundus.

The *posterior surface* is flattened from side to side and slightly convex from above downwards ; it is separated by its sheath and some loose connective tissue from the rectum, and is distant about 4 cm. from the anus (fig. 1223). Near its upper border there is a depression through which the two ejaculatory ducts enter the prostate. This depression serves to divide the posterior surface into a lower, larger, and an upper, smaller part. The upper, smaller part constitutes the *median lobe* of the prostate and intervenes between the ejaculatory ducts and the urethra ; it varies greatly in size, and in some cases is destitute of glandular tissue. The lower larger portion sometimes presents a shallow median furrow, which imperfectly separates it into *right* and *left lobes* ; these form the main mass of the gland and are directly continuous with each other behind the urethra ; they are connected in front of the urethra by a band which is named the *isthmus* ; the latter consists of fibromuscular tissue and is devoid of glandular substance.

The *anterior surface* is narrow and convex from side to side and extends from the apex to the base. It lies about 2 cm. behind the pubic symphysis, from which it is separated by a plexus of veins and a quantity of loose fatty tissue. Near its upper end it is connected to the pubic bones by the puboprostatic ligaments. The urethra emerges from this surface a little above and in front of the apex of the prostate.

The *inferolateral surfaces* are prominent, and are covered by the anterior portions of the Levatores ani, which are, however, separated from the gland by a plexus of veins imbedded in connective tissue which forms the lateral part of the sheath of the organ.

The prostate measures about 4 cm. transversely at the base, about 2 cm. in its anteroposterior, and 3 cm. in its vertical, diameter. Its weight is about 8 gm. It is invested by a fibrous sheath derived from the pelvic fascia. On each side the sheath consists of connective tissue in which are imbedded the veins of the prostatic venous (pudendal) plexus (fig. 611). In front, it is continuous with the puboprostatic ligaments (p. 574) and, below, it blends with the fascia on the deep surfaces of the Sphincter urethræ and the Transversus perinei profundus, and with the perineal body (fig. 608). The posterior wall of the sheath has a different constitution and is non-vascular. In the male fœtus, at the fourth month, the rectovesical peritoneal pouch extends downwards to the pelvic floor and separates the prostate from the rectum. The lower part of this recess becomes obliterated and the fused peritoneal layers form the posterior wall of the prostatic sheath.* This fibrous membrane has been termed the *rectovesical fascia*. Above, it extends upwards over the posterior aspects of the

* G. Elliot Smith (*Journal of Anatomy*, vol. xlii.).

seminal vesicles and the vasa deferentia and is connected to the peritoneal floor of the rectovesical pouch (fig. 608). On each side, it is connected to the posterior ligament of the bladder (p. 1374) and, below, where it becomes closely adherent to the prostate, it is lost in the perineal body. The anterior portions of the Levatores ani pass backwards from the os pubis and embrace the sides of the prostate; from the support they afford to this organ they are named the *Levatores prostatæ.*

The prostate is perforated by the urethra and the ejaculatory ducts and contains the prostatic utricle. The urethra usually lies along the junction of its anterior with its middle one-third. The ducts pass obliquely downwards and forwards through the posterior part of the prostate, and open into the prostatic portion of the urethra (p. 1377).

Structure.—The prostate is enveloped by a thin but firm capsule, distinct from the sheath derived from the pelvic fascia, which contains a plexus of veins. This capsule is firmly adherent to the prostate and is structurally continuous with the stroma of the gland, being composed of the same tissues, viz. non-striped muscle and fibrous tissue. The substance of the prostate is of a pale reddish-grey colour, of great density, and not easily torn. It consists of glandular substance and muscular tissue.

The *muscular tissue* constitutes the proper stroma of the prostate; the connective tissue being very scanty, and merely forming, between the muscular fibres, thin trabeculæ in which the vessels and nerves of the gland ramify. The muscular tissue is arranged as follows: immediately beneath the capsule there is a dense layer, which forms an investing sheath for the gland; around the prostatic part of the urethra a dense layer of circular fibres is continuous above with the internal layer of the muscular coat of the bladder, and blends below with the fibres surrounding the membranous portion of the urethra; between these two layers strong bands of muscular tissue decussate freely, and form meshes in which the glandular structure of the organ is imbedded. In that part of the gland which is situated in front of the urethra the muscular tissue is especially dense, and there is here little or no glandular tissue; while in that part which is behind the urethra the muscular tissue presents a wide-meshed structure, which is densest at the base of the gland—that is, near the bladder—becoming looser and more sponge-like towards the apex.

The *glandular substance* is composed of numerous follicles the lining of which frequently shows papillary elevations. The follicles open into elongated canals which join to form from twelve to twenty small excretory ducts. They are connected together by areolar tissue, supported by prolongations from the fibrous capsule and muscular stroma, and enclosed in a delicate capillary plexus. The epithelium which lines the canals and the follicles is of the columnar variety. The prostatic ducts open into the floor of the prostatic portion of the urethra, and are lined by two layers of epithelium, the inner layer consisting of columnar and the outer of small cubical cells. Small colloid masses, known as amyloid bodies, are often found in the gland tubes. The prostatic secretion and the secretion of the seminal vesicle together form the bulk of the seminal fluid.

Vessels and Nerves.—The *arteries* supplying the prostate are derived from the internal pudendal, inferior vesical and middle rectal (hæmorrhoidal) arteries. Its *veins* form a plexus around the sides and base of the gland; they receive in front the dorsal vein of the penis, and end in the internal iliac (hypogastric) veins. The *lymph vessels* are described on p. 874. The *nerves* are derived from the pelvic plexus (p. 1152).

Applied Anatomy.—By means of the finger introduced into the rectum, the surgeon detects enlargement or other disease of the prostate; he can feel the apex of the gland, and is able to direct the point of a catheter, when its introduction is attended with difficulty either from injury or disease of the membranous or prostatic portions of the urethra. The prostate is occasionally the seat of suppuration, due to either gonorrhœa or tuberculous disease. The gland is enveloped in a dense unyielding capsule, which determines the course of the abscess, and also explains the great pain which is present in the acute form of the disease. The abscess most frequently bursts into the urethra, the direction in which there is least resistance, but may burst into the rectum, or more rarely in the perineum. In advanced life the prostate often becomes considerably enlarged and projects into the bladder so as to impede the passage of the urine. According to Messer's researches, conducted at Greenwich Hospital, it would seem that such obstruction exists in 20 per cent. of all men over sixty years of age. In some cases the condition affects principally the lateral lobes, which may undergo considerable enlargement without causing much inconvenience. In other cases the median lobe enlarges most, and even a small enlargement of this lobe may act injuriously, by forming a sort of valve over the internal urethral orifice, preventing the passage of the urine; and the more the patient strains, the more completely will it block the opening into the urethra.

The Bulbo-urethral Glands

The **bulbo-urethral glands** are two small, rounded and somewhat lobulated bodies, of a yellow colour. Each is about the size of a pea, and is placed lateral to the membranous portion of the urethra, deep to the perineal membrane. They lie above the bulb of the penis, and are enclosed by the transverse fibres of the Sphincter urethræ. They gradually diminish in size as age advances.

The excretory duct of each gland is nearly 3 cm. long ; it passes obliquely forwards beneath the mucous membrane, and opens by a minute orifice on the floor of the spongy portion of the urethra about 2·5 cm. below the perineal membrane.

Structure.—Each gland is made up of several lobules which are held together by a fibrous investment. Each lobule consists of a number of acini, lined by columnar epithelial cells. The secretion of the bulbo-urethral glands is an additional constituent of the seminal fluid, but the glands are very small in man as compared with many animals, and the part which they play is probably very subsidiary.

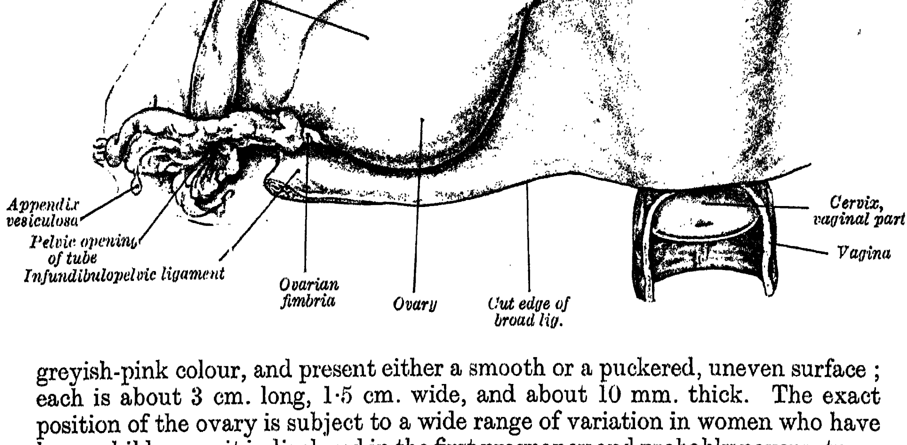
THE FEMALE GENITAL ORGANS

The female genital organs consist of an internal and an external group. The *internal organs* are situated within the pelvis, and consist of the ovaries, the uterine tubes, the uterus and the vagina. The *external organs* are placed below and in front of the pubic arch. They comprise the mons pubis, the labia majora et minora pudendi, the clitoris, the bulbus vestibuli and the greater vestibular glands.

The Ovaries

The **ovaries**, two in number, are homologous with the testes in the male. They are situated one on each side of the uterus in relation to the lateral wall of the pelvis, and attached to the posterior or upper layer of the broad ligament of the uterus, behind and below the uterine tube (fig. 1240). They are of a

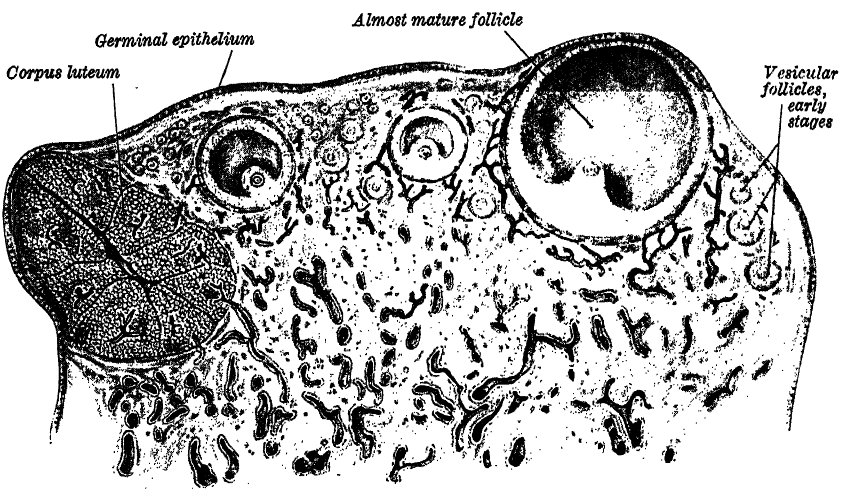
Fig. 1240.—The uterus and the left broad ligament. Posterior surface. The broad ligament has been spread out and the ovary drawn downwards.



greyish-pink colour, and present either a smooth or a puckered, uneven surface ; each is about 3 cm. long, 1·5 cm. wide, and about 10 mm. thick. The exact position of the ovary is subject to a wide range of variation in women who have borne children, as it is displaced in the first pregnancy and probably never returns

again to its original position. The description here given applies to that of the nulliparous woman. In the erect posture the long axis of the ovary is vertical, and the gland presents a lateral and a medial surface, a tubal and a uterine extremity, and a mesovarian and a free border. The ovary lies in a depression, named the *ovarian fossa*, on the lateral wall of the pelvis ; this fossa is bounded in front by the obliterated umbilical artery, and behind by the ureter and the internal iliac (hypogastric) artery. The *tubal extremity* is near the external iliac vein ; to it are attached the ovarian fimbria of the uterine tube and a fold of peritoneum, named the *infundibulopelvic ligament* (suspensory ligament of the ovary), which passes upwards over the iliac vessels and contains the ovarian vessels and nerves. The *uterine extremity* is directed downwards towards the pelvic floor ; it is usually narrower than the tubal extremity, and is attached to the lateral angle of the uterus, immediately behind and below the uterine tube, by a rounded cord termed the *ligament of the ovary*, which lies within the broad ligament and contains some non-striped muscular fibres. The *lateral surface* is in contact with the parietal peritoneum which lines the ovarian fossa ; it separates the ovary from the peritoneal tissue and the obturator vessels

Fig. 1241.—A section through the ovary. Semidiagrammatic.



and nerve. The *medial surface* is to a large extent covered with the uterine tube and the peritoneal recess between this aspect of the gland and the mesosalpinx is termed the *bursa ovarica*. The *mesovarian border* is straight and is directed towards the obliterated umbilical artery ; it is attached to the back of the broad ligament by a short fold named the *mesovarium*. Between the two layers of this fold the blood-vessels and nerves pass to the hilum of the ovary. The *free border* is convex, and is directed towards the ureter. The uterine tube arches over the ovary, running upwards in relation to its mesovarian border, curving over its tubal extremity, and then passing downwards on its free border and medial surface.

In the fœtus, the ovaries are situated, like the testes, in the lumbar region near the kidneys, but they gradually descend into the pelvis (p. 193).

Structure (fig. 1241).—The surface of the ovary is covered with a layer of cubical cells. This *germinal epithelium* gives to the ovary a dull grey colour as compared with the shining smoothness of the peritoneum ; the transition between the flattened endothelium of the peritoneum and the cubical cells covering the ovary is usually marked by a line around the anterior, or mesovarian, border of the ovary.

The ovary consists of a stroma, or framework, in the meshes of which a number of vesicular ovarian follicles are imbedded.

The *stroma* is abundantly supplied with blood-vessels, and consists for the most part of spindle-shaped cells with a small amount of ordinary connective tissue. Many of these cells are unstriped muscle-cells. On the surface of the organ there is a condensed layer known as the *tunica albuginea*. The stroma of the ovary also contains groups of *interstitial cells* resembling those of the testis.

Vesicular ovarian (*Graafian*) *follicles*.—When a section is made through an ovary, numerous vesicles of various sizes are seen; they are the follicles, or ovisacs containing the ova. Immediately beneath the tunica albuginea there is a layer of stroma, called the *cortical layer*, characterised by the presence of a large number of ova in an early stage of development. At this stage each ovum is surrounded by a single layer of smaller, cubical cells. These primitive follicles are numerous in the ovary of the child.

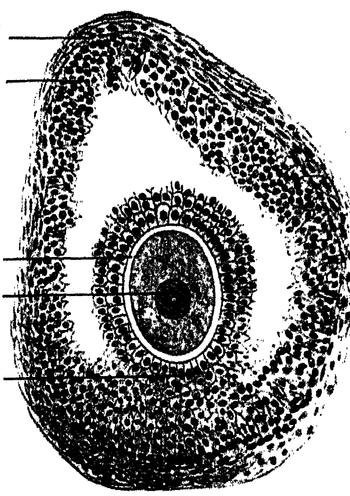
After puberty some of these primitive ovarian follicles increase in size; the cells investing the ovum multiply, and later a cavity, named the *antrum folliculi*, appears between the cells thus formed. This cavity is filled with *liquor folliculi*, a transparent, albuminous fluid which nourishes and protects the ovum. The liquor folliculi splits the investing cells into two strata, an outer named the *stratum granulosum*, and an inner named the *cumulus ovaricus*; the latter surrounds the ovum * and is attached at one spot to the stratum granulosum (fig. 1241). Thomson † is of opinion that the cumulus may be attached to the stratum granulosum at any part of the circumference of the follicle. In the earlier stages of the development of the follicle the stratum granulosum is made up of several layers of cubical cells, but in the matured follicle it consists of a single layer, and in some instances this may disappear.

Scattered amongst the cells of the cumulus ovaricus and stratum granulosum are certain structures known as the *bodies of Call and Exner*, the cells surrounding which are radially arranged; in the advanced stages of the growth of the follicle these bodies are found only in the cumulus. Each consists of a more or less homogeneous mass of protoplasm, which, in its reactions to certain stains, resembles the coagulated liquor folliculi. These bodies become vacuolated, and tend to break down, and it is therefore probable that the liquor folliculi is formed, in the first instance, by their dissolution.

A fully developed or 'ripe' ovarian follicle measures at least 10 mm. † and is surrounded by a capsule [*theca folliculi*] derived from the ovarian stroma, and composed of an internal and an external tunic. The *tunica interna* consists of loosely-arranged, round or spindle-shaped cells, and is pervaded by a capillary plexus. The vascularity of this tunic increases as the follicle matures, and the capillary vessels then extend between the cells of the attached part of the cumulus. Between the tunica interna and the stratum granulosum which lines it, there is a thin *external limiting membrane* (basal membrane). The *tunica externa* consists of firmer and less vascular tissue than the tunica interna, and contains a considerable quantity of non-striped muscular fibres.

The mature follicle approaches, and ultimately bursts on, the surface of the ovary, and the escaping ovum, surrounded by the cells of the cumulus ovaricus, is grasped by the fimbriated end of the uterine tube, and is conveyed along this tube to the cavity of the uterus.

FIG. 1242.—A section through an ovarian follicle of a cat. ×50.



Robinson ‡ has investigated the formation, rupture, and closure of the ovarian follicles in ferrets, and has shown that in these animals a fluid, named by him the *secondary liquor folliculi*, appears between the cells of the cumulus ovaricus and takes part in the final distension of the follicle which precedes rupture. It would seem probable that a similar process occurs in the human follicle and accounts both for the rupture of the follicle and for the liberation of the ovum with its cumulus from the stratum granulosum.

The maturation of the follicles and ova continues uninterruptedly from puberty to the end of the reproductive period of woman's life. In all probability only one of the numerous follicles which are visible on the surface of an ovary at any particular time gives rise to a normal mature ovum. The others undergo atretic changes and become disintegrated. In these cases the rupture of the follicle liberates an abnormal ovum.

* The ovum is described on pp. 44 to 46.

† Consult, in this connexion, articles by Arthur Thomson on "The Ripe Human Graafian Follicle," *Journal of Anatomy*, vol. liv., and by Edgar Allen and others on "Human Ova from Large Follicles," *American Journal of Anatomy*, vol. xlvi., no. 1.

‡ Arthur Robinson, *Transactions of the Royal Society of Edinburgh*, vol. lii. part ii.

Corpus luteum.—After the discharge of the ovum a series of changes occurs within the vesicular ovarian follicle which results in the formation of a structure named the *corpus luteum.* When fully developed this consists of numerous cells, separated from one another by delicate strands of vascular connective tissue; in the centre of the follicle this tissue is condensed to form a mass which is devoid of cells. The cells of the corpus luteum are of two kinds, (*a*) *lutein cells,* which are large, very numerous, and contain yellow pigment, and (*b*) *paralutein cells,* which are small and less numerous. The lutein cells are derived from the cells of the stratum granulosum, and the paralutein cells from the cells of the tunica interna, of the vesicular ovarian follicle.*

If the discharged ovum is not fertilised the corpus luteum quickly degenerates, and within two months is reduced to a small cicatrix, but if the ovum is fertilized the corpus luteum increases in size, and, by the middle of pregnancy, may measure about 2·5 cm. in diameter. During the later months of pregnancy the lutein cells lose their colour, and the size of the corpus luteum diminishes, so that by the end of pregnancy its diameter is reduced to about 1 cm.†

Vessels and Nerves.—The *arteries* of the ovaries and uterine tubes are the ovarian arteries from the aorta (p. 772). Each anastomoses in the mesosalpinx with the corresponding uterine artery: it gives some branches to the uterine tube, and others which traverse the mesovarium and enter the hilum of the ovary. The *veins* emerge from the hilum in the form of a plexus, named the *pampiniform plexus*; the ovarian vein is formed from this plexus, and leaves the pelvis in company with the artery (p. 840). The *lymph vessels* are described on p. 874. The *nerves* are derived from the hypogastric or pelvic plexus, and from the ovarian plexus, the uterine tube receiving a branch from one of the uterine nerves.

Epoöphoron (fig. 1240).—The epoöphoron lies in the lateral part of the mesosalpinx between the ovary and the uterine tube, and consists of a few short tubules [*tubuli epoöphori*] which converge towards the ovary while their opposite ends open into a rudimentary duct, named the *ductus epoöphori,* which runs in the broad ligament of the uterus, parallel with the lateral part of the uterine tube.

In a small proportion of subjects the duct of the epoöphoron can be followed alongside the uterus to near the level of the internal os. Here it pierces the muscular wall of the uterus and descends in the cervix uteri, gradually approaching the mucous membrane, without however quite reaching it. The duct then runs downwards in the lateral wall of the vagina and ends at, or close to, the free margin of the hymen.

Paroöphoron.—The paroöphoron consists of a few scattered rudimentary tubules, best seen in the child, situated in the broad ligament between the epoöphoron and the uterus.

The tubules of the epoöphoron and of the paroöphoron are remnants of the tubules of the mesonephros; the duct of the epoöphoron is a persistent portion of the mesonephric (Wolffian) duct.

The Uterine Tubes (figs. 1240, 1244)

The **uterine tubes**, two in number, transmit the ova from the ovaries to the cavity of the uterus and are situated in the upper margins of the broad ligaments of the uterus. Each tube is about 10 cm. long, and one end of it opens into the superior angle of the cavity of the uterus, the other into the peritoneal cavity close to the ovary. The opening into the uterine cavity is very small, and only admits a fine bristle; the opening into the peritoneal cavity is named the *ostium pelvinum* (ostium abdominale), and when its muscular wall is relaxed has a diameter of about 3 mm. The pelvic ostium is situated at the bottom of a trumpet-shaped expansion of the uterine tube, termed the *infundibulum,* the circumference of which is prolonged into a varying number of irregular processes, called *fimbriæ,* and therefore this extremity of the tube is sometimes called the *fimbriated end.* The inner surfaces of the fimbriæ are lined by mucous membrane, and in the larger fimbriæ this exhibits longitudinal folds which are continuous with similar folds in the mucous lining of the infundibulum. One fimbria, longer and more deeply grooved than the others, is attached to the tubal extremity of the ovary, and is named the *ovarian fimbria.* The infundibulum opens into the *ampulla* of the tube, which is thin-walled and tortuous and forms rather more than one-half the entire length of the tube. The ampulla is succeeded by the *isthmus,* which is round and cord-like and constitutes approximately the medial one-third of the tube. The part continued from the isthmus through the wall of the uterus is about 1 cm. long, and is named the *pars uterina tubæ.*

* Wilfred Shaw, *British Medical Journal,* Nov. 21, 1925, p. 952.

† Consult *The Physiology of Reproduction,* by F. H. A. Marshall, 1910.

The uterine tube is directed laterally as far as the uterine extremity of the ovary, and then ascends along the mesovarian border to the tubal extremity of the ovary, over which it arches; finally it turns downwards and ends in relation to the free border and medial surface of the ovary. In connexion with the fimbriæ of the uterine tube, or with the broad ligament close to them, there are frequently one or more small pedunculated vesicles; these are termed the *appendices vesiculosæ* (fig. 1240).

Fig. 1243.—Transverse section of a human uterine tube. Stained with hæmatoxylin and eosin. × 15.

Structure (fig. 1243).—The uterine tube consists of three coats: serous, muscular and mucous. The *external*, or *serous, coat* is peritoneal. The *middle*, or *muscular, coat* consists of an external longitudinal and an internal circular layer of non-striped muscular fibres continuous with those of the uterus. The *internal*, or *mucous, coat* is continuous with the mucous lining of the uterus. It is thrown into longitudinal folds, which in the ampulla are much more extensive than in the isthmus. The lining epithelium is columnar and ciliated. This form of epithelium is also found on the inner surfaces of the fimbriæ; while on the outer or serous surfaces of these processes the epithelium gradually merges into the endothelium of the peritoneum.

Applied Anatomy.—Pelvic peritonitis occurs much more frequently in the female than in the male, because infective conditions of the vagina, uterus or uterine tube may involve the peritoneum by direct spread, owing to the communication which exists between the peritoneal cavity and the lumen of the tube through the pelvic ostium. When pus collects in the recto uterine pouch, it may be palpated through the posterior fornix of the vagina, on account of the peritoneal relations of the upper part of the posterior vaginal wall (p. 1405).

Tubal inflammation (*salpingitis*) is usually due to infections which have spread upwards by way of the vagina and uterus. In many cases the fimbriated end of the tube may become closed by adhesions and a collection of pus forms in the tube (*pyosalpinx*).

Fertilisation of the ovum (p. 51) is believed to occur in the uterine tube, and the fertilised ovum normally is then passed on into the uterus; the ovum, however, may adhere to and undergo development in the tube, giving rise to the commonest variety of *ectopic gestation*. In such cases the amnion and chorion are formed, but a true decidua is never present; and the gestation usually ends by extrusion of the ovum through the pelvic ostium, although it is not uncommon for the tube to rupture into the peritoneal cavity, this being accompanied by severe hæmorrhage, and necessitating surgical interference.

The Uterus (figs. 1240, 1244, 1245)

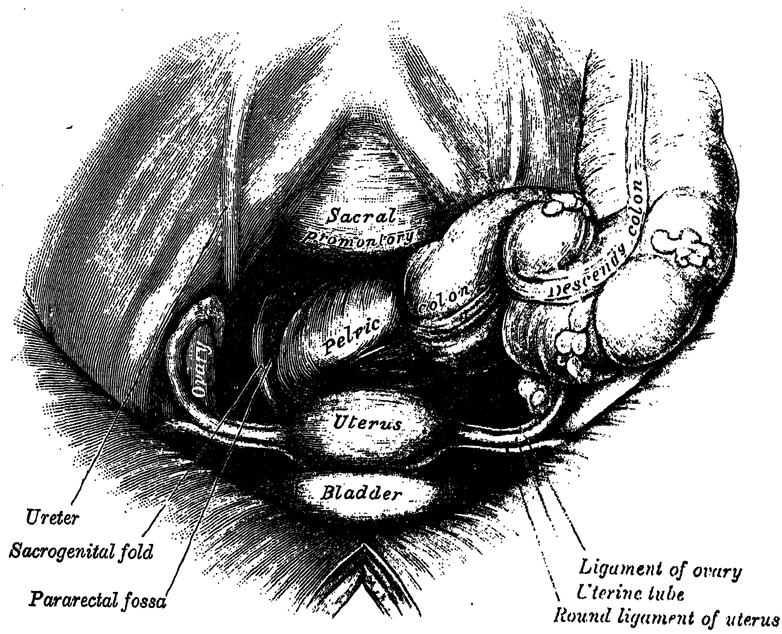
The **uterus**, or **womb**, is a hollow, thick-walled, muscular organ situated in the pelvic cavity between the urinary bladder in front and the rectum behind. Into its upper part the uterine tubes open, one on each side, while below, its cavity communicates with that of the vagina. When the ova are discharged from the ovaries they are carried to the uterine cavity through the uterine tubes. If an ovum be fertilised it imbeds itself in the uterine wall and is normally retained in the uterus until prenatal development is completed, the uterus undergoing changes in size and structure to accommodate itself to the needs of the growing embryo. After parturition the uterus returns almost to its former condition, but traces of its enlargement remain. For general descriptive purposes the adult virgin uterus is taken as the type form.

In the virgin state the uterus is flattened from before backwards and is pyriform in shape, with the narrow end directed downwards and backwards. It lies between the bladder below and in front, and the pelvic colon and rectum above and behind, and is completely below the level of the pelvic inlet. Its upper part is covered with peritoneum and lies in the peritoneal cavity, while its lower portion is imbedded in the connective tissue of the pelvis.

The long axis of the uterus usually lies approximately in the axis (p. 379) of the pelvic inlet, but as the organ is freely movable its position varies with the state of distension of the bladder and rectum. Except when much displaced by a distended bladder, it forms an angle with the vagina, since the axis of the vagina corresponds to the axes of the cavity and outlet (p. 380) of the pelvis.

The uterus measures about 7·5 cm. in length, 5 cm. in breadth at its upper part, and nearly 2·5 cm. in thickness; it weighs from 30 to 40 gm. It is divisible into two portions. On the surface, a little below the middle, there is a

FIG. 1244.—A female pelvis and its contents. Viewed from above and in front.



slight constriction, which corresponds to a narrowing of the uterine cavity, named the *internal os* of the uterus. The portion above the internal os is termed the *body*, and that below, the *cervix*. The part of the body which lies above a plane passing through the points of entrance of the uterine tubes is known as the *fundus*.

Body.—The body gradually narrows from the fundus to the internal os.

The *vesical*, or *anterior, surface* is in apposition with the urinary bladder. It is flattened and covered with peritoneum, which is reflected on to the bladder as the utero-vesical fold at the level of the internal os. The recess or pouch between the bladder and the uterus is named the *utero-vesical pouch*.

The *intestinal*, or *posterior, surface* is convex transversely, and is covered with peritoneum, which is continued downwards on the cervix uteri and the upper part of the vagina before being reflected backwards on to the rectum (fig. 1245). It is in relation with the pelvic colon, from which it is usually separated by the terminal coil of the ileum.

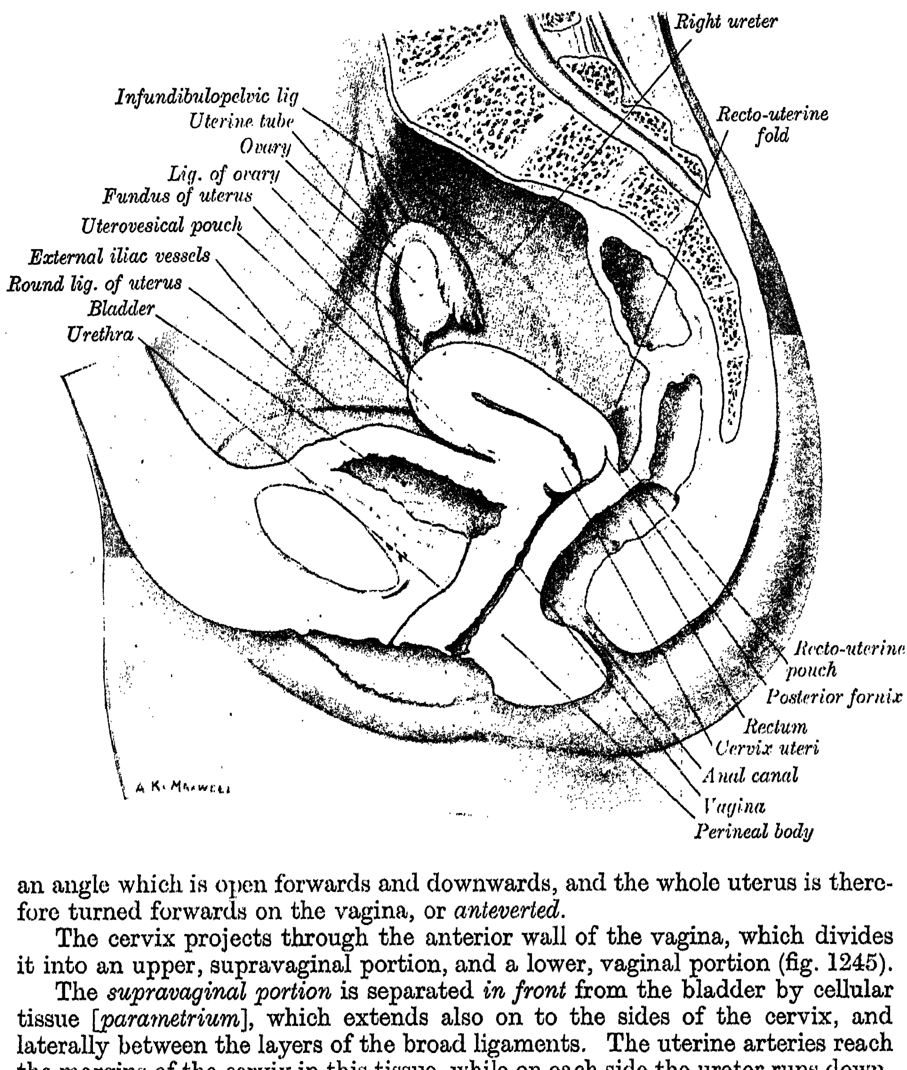
The *fundus* is convex in all directions, and covered with peritoneum continuous with that on the vesical and intestinal surfaces. Some coils of small intestine, and occasionally the distended pelvic colon rest on it.

The *margins* are slightly convex. At the upper end of each the uterine tube pierces the uterine wall. Below and in front of this point the round liga-

ment of the uterus is fixed; below and behind it the ligament of the ovary is attached. These three structures lie within a fold of peritoneum, named the broad ligament, which stretches from the margin of the uterus to the lateral wall of the pelvis.

Cervix.—The cervix is about 2·5 cm. in length; it is narrower and more cylindrical than the body, and is a little wider in the middle than above or below. Owing to its relationships it is less freely movable than the body, so that its long axis is seldom in the same straight line as that of the body. The long axis of the uterus as a whole presents the form of a curved line with its concavity forward, and the organ is described as being *anteflexed*. In extreme cases there may be an angular bend at the region of the internal os—acute anteflexion. The long axis of the cervix meets the long axis of the vagina at

FIG. 1245.—A median sagittal section through the female pelvis.



an angle which is open forwards and downwards, and the whole uterus is therefore turned forwards on the vagina, or *anteverted*.

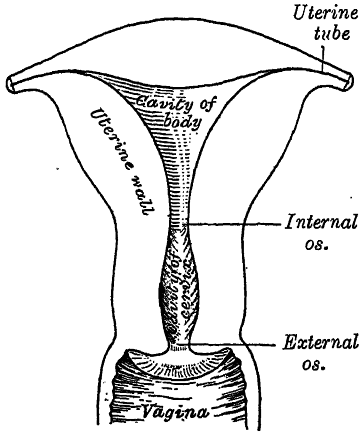
The cervix projects through the anterior wall of the vagina, which divides it into an upper, supravaginal portion, and a lower, vaginal portion (fig. 1245).

The *supravaginal portion* is separated *in front* from the bladder by cellular tissue [*parametrium*], which extends also on to the sides of the cervix, and laterally between the layers of the broad ligaments. The uterine arteries reach the margins of the cervix in this tissue, while on each side the ureter runs downwards and forwards in it at a distance of about 2 cm. from the cervix. *Posteriorly* the supravaginal cervix is covered with peritoneum, which is prolonged below on to the posterior vaginal wall, whence it is reflected to the rectum, forming the recto-uterine pouch (p. 1307). It is in relation with the rectum, from which it may be separated by the terminal coil of the ileum.

The *vaginal portion* of the cervix projects into the anterior wall of the vagina between the vaginal fornices (p. 1404). On its projecting rounded

extremity there is a small, depressed, somewhat circular aperture, termed the *external os of the uterus*, through which the cavity of the cervix communicates with that of the vagina. The external os is bounded by two lips, an anterior and a posterior, of which the anterior is the shorter and thicker, although, on account of the slope of the cervix, it projects lower than the posterior. Normally both lips are in contact with the posterior vaginal wall.

FIG. 1246.—The posterior half of the uterus and upper part of the vagina.



Interior of the uterus (fig. 1246).—The cavity of the uterus is small in comparison with the size of the organ.

The **cavity of the body** is a mere slit, flattened from before backwards. It is triangular in shape, the base being formed by the internal surface of the fundus between the orifices of the uterine tubes, the apex by the internal os of the uterus; through this orifice the cavity of the body communicates with the canal of the cervix.

The **canal of the cervix** is somewhat fusiform, flattened from before backwards, and broader at the middle than at the ends. It communicates above, through the internal os, with the cavity of the body, and below, through the external os, with the vaginal cavity. The wall of the canal presents an anterior and a posterior longitudinal ridge, from each of which a number of small oblique columns, named the *palmate folds*, proceed, giving the appearance of branches from the stem of a tree; to this arrangement the name *arbor vitæ uteri* is applied. The folds on the two walls are not opposed, but fit between one another so as to close the cervical canal.

The total length of the uterine cavity from the external os to the fundus is about 6 cm.

According to H. Stieve,* the upper third or less of the cervix, which has been termed the **isthmus**, presents certain features which differentiate it from the rest. He has pointed out that, although it is unaffected in the first month of pregnancy, it is gradually taken up into the body of the uterus during the second month and forms the '*lower uterine segment*' of English obstetricians. The fœtal membranes, though firmly blended with the rest of the uterine mucosa, are not attached to the lower uterine segment. In the non-pregnant uterus the isthmus undergoes changes associated with menstruation similar to, but less pronounced than those which occur in the body of the organ. Histologically the isthmus resembles the body more than it resembles the cervix; its lining epithelium is low cylindrical in type and is ciliated; its mucous coat is thinner; and the glands are fewer in number.

Changes affecting the uterus.—The form, size and situation of the uterus vary at different periods of life and under different circumstances.

In the fœtus the uterus projects above the inlet of the pelvis (fig. 1247). The cervix is considerably larger than the body.

At puberty the uterus is pyriform in shape, and weighs from 14 to 17 gms. The fundus is just below the level of the inlet of the pelvis. The palmate folds are distinct, and extend to the upper part of the cavity.

The position of the uterus *in the adult* is liable to considerable variation, depending chiefly on the condition of the bladder and rectum. When the bladder is empty the entire uterus is directed forwards, and is at the same time bent on itself at the junction of the body and cervix, so that the body lies upon the bladder. As the latter fills, the uterus gradually becomes more and more erect, until with a fully distended bladder the fundus may be directed towards the sacrum.

During menstruation the organ is enlarged, and more vascular, and its surfaces are rounder; the external os is rounded, its lips swollen, and the lining membrane of the body is thicker, softer and of a darker colour.

During pregnancy the uterus becomes enormously enlarged, and in the eighth month reaches the epigastric region. The increase in size is partly due to growth of pre-existing muscular fibres, and partly to development of new fibres.

* H. Stieve, "Der Halsteil der menschlichen Gebärmutter," Leipzig, 1927. *See also* O. Frankl, *Journal of Obstetrics and Gynecology of the British Empire*, vol. xl. 1933.

After parturition the uterus nearly regains its usual size, weighing about 42 gm.; but its cavity is larger than in the virgin state, its vessels are tortuous, and its muscular layers are more defined; the external os is more prominent, and its edges present one or more fissures.

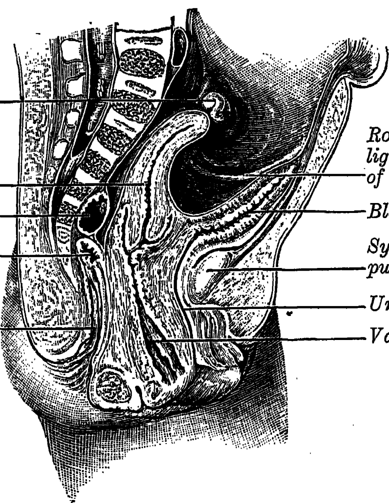
In old age the uterus becomes atrophied, and paler, and denser in texture; a more distinct constriction separates the body and cervix. The internal os is frequently, and the external os occasionally, obliterated, while the lips almost entirely disappear.

Structure.—The uterus is composed of three coats: an external or serous, a middle or muscular, and an internal or mucous.

The *serous coat* is derived from the peritoneum. In the lower one-fourth of the intestinal surface the peritoneum is not closely connected with the uterus, being separated from it by a layer of loose cellular tissue and some large veins.

The *muscular coat* forms the chief bulk of the substance of the uterus. In the virgin it is dense, firm, of a greyish colour, and cuts almost like cartilage. It is thick opposite the middle of the body and fundus, and thin at the orifices of the uterine tubes. It consists of bundles of unstriped muscular fibres, intermixed with areolar tissue, blood-vessels, lymph

Fig. 1247.—A sagittal section through the pelvis of a new-born female child. Some coils of the small intestine which intervened between the uterus and the bladder have been removed.



vessels and nerves. During pregnancy the muscular tissue becomes more prominently developed, the fibres being greatly enlarged. Although the unstriped muscular fibres interlace in all directions, they are arranged in three more or less distinct layers: external, middle and internal.

The external layer consists chiefly of longitudinal fibres, which pass over the fundus, and, converging at the lateral angle on each side of the uterus, are continued on the uterine tube, the round ligament and the ligament of the ovary: some passing at each side into the broad ligament, and others running backwards from the cervix into the uterosacral ligaments. The middle layer of fibres is the thickest, but presents no regularity in its arrangement, being disposed longitudinally, obliquely and transversely; it contains the larger blood-vessels. The internal layer consists of longitudinal and circular fibres; at the internal os the circular fibres form a sphincter. The deep ends of the uterine glands come into close relation with the fibres of the internal layer.

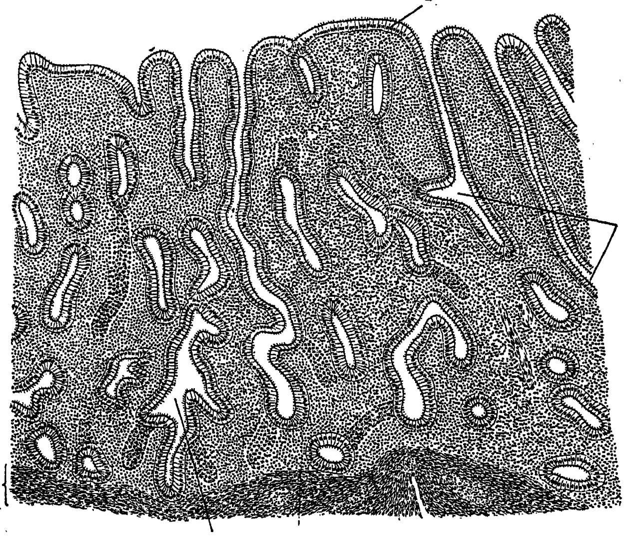
The *mucous membrane*, often named the *endometrium* (fig. 1248), lines the uterus, and is continuous, through the fimbriated extremities of the uterine tubes, with the peritoneum; and, through the external os of the uterus, with the lining of the vagina.

In the body of the uterus the mucous membrane is smooth and of pale red colour, and its free surface is covered with columnar epithelium. Prior to puberty the epithelium is ciliated, but owing to its periodic destruction in the process of menstruation and pregnancy it is usually non-ciliated over large areas in the adult uterus. The mucous membrane consists of an embryonic nucleated and highly cellular form of connective tissue in which run blood-vessels and numerous lymphatic spaces. It contains many tube-like *uterine glands*, which are lined with ciliated columnar epithelium and open into the cavity of the uterus. The glands are small in the unimpregnated uterus, but shortly after impregnation they become enlarged and elongated, presenting a contorted or waved appearance.*

* Arthur Thomson (*British Medical Journal*, January 7th, 1922) discusses whether the uterine glands possess a secretory or an absorbent function.

In the cervix uteri the mucous membrane is raised into two median elevations, one on the anterior, the other on the posterior, wall of the canal; from these median elevations numerous ridges (palmate folds) run upwards and laterally. In the upper two-thirds of the cervix, the mucous membrane is provided with numerous, deep, glandular follicles which secrete a clear, viscid, alkaline mucus; and in addition, extending through the whole length of the canal a variable number of little cysts are found, presumably follicles which have become occluded and distended with retained secretion. They are called the *ovula Nabothi*. The mucous membrane covering the lower one-half of the cervical canal presents numerous papillæ. The epithelium of the upper two-thirds is cylindrical and ciliated, but below this it loses its cilia, and, close to the external os, changes to stratified squamous. On the vaginal surface of the cervix the epithelium is similar to that lining the vagina, viz. stratified squamous.

FIG. 1248.—A vertical section through the mucous membrane of a human uterus. (Sobotta.)



Vessels and Nerves.—The *arteries* of the uterus are the uterine branch of the internal iliac artery (p. 777), and the ovarian branch of the abdominal aorta (p. 772). They are remarkable for their tortuous course in the substance of the organ (fig. 1249). The termination of the ovarian artery meets that of the uterine artery, and forms an anastomotic trunk from which branches are given off to supply the uterus. The *veins* are of large size, and correspond with the arteries. They end in the uterine venous plexuses. In the impregnated uterus the arteries carry the blood to, and the veins convey it away from, the intervillous space of the placenta (fig. 108). The *lymph vessels* are described on p. 874. The *nerves* are derived from the hypogastric and ovarian plexuses, and from the pelvic splanchnic nerves (S 2, 3, and 4).

There is reason to believe that impulses conveyed through the sympathetic nerves produce contraction of the circular, and inhibition of the longitudinal, muscle-fibres of the uterus, and that impulses conveyed through the pelvic splanchnics (parasympathetic) produce exactly opposite effects, i.e. they cause contraction of the longitudinal, and inhibition of the circular, fibres.*

Applied Anatomy.—A certain amount of anteversion or retroversion of the uterus can take place without the conditions being regarded as pathological, but when the degree of flexion at the junction of the body with the cervix becomes considerable it must be regarded as a morbid condition. This is especially true of retroversion combined with retroflexion. Retroversion alone is falling back of the whole uterus, so that the cervix points forwards towards the os pubis; retroflexion is a bending backwards of the body, the cervix remaining in its normal position. The two conditions are usually combined. Prolapse of the

* Consult (1) *The Physiology of Reproduction*, by Francis H. A. Marshall, and (2) an article on the innervation of the uterus by Beckwith Whitehouse and Henry Featherstone, *British Medical Journal*, September 1923, p. 406.

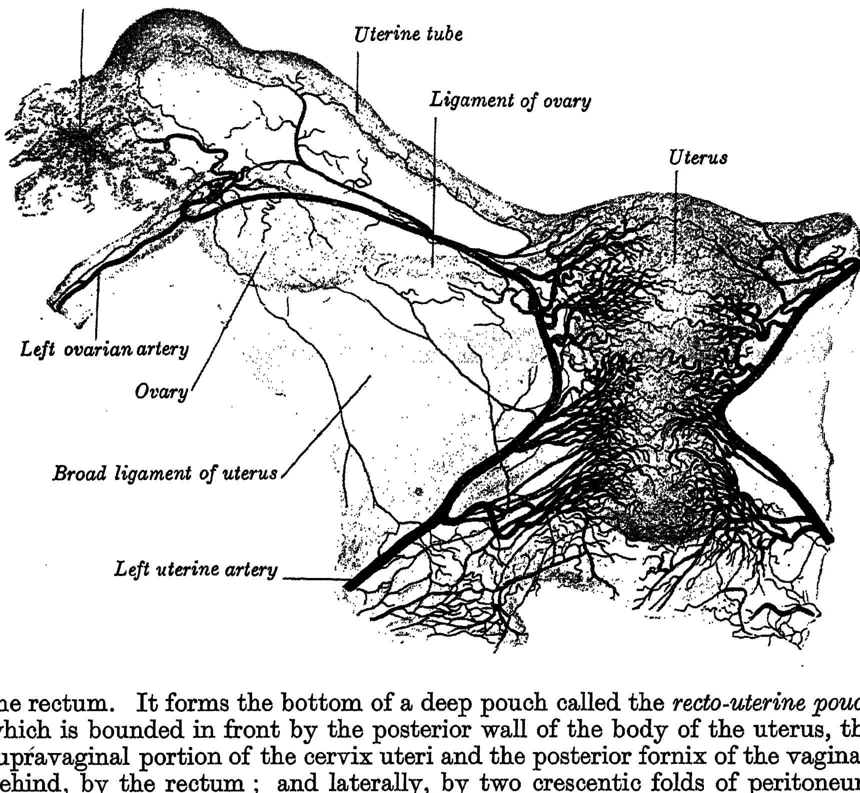
uterus is another common infirmity. The organ sinks to an abnormally low level in the pelvis, and sometimes protrudes beyond the vulva. This condition is usually due to imperfect repair of the pelvic floor following a tear of the perineum during parturition (p. 576).

Ligaments.—The uterus is connected to the bladder, the rectum and the walls of the pelvis by a number of ligaments; some of these are peritoneal ligaments or folds, while others consist of unstriped muscle and fibrous tissue.

The *anterior ligament* consists of the *utero-vesical fold* of peritoneum, which is reflected on to the bladder from the front of the uterus, at the junction of the cervix and body.

The *posterior ligament* consists of the *rectovaginal fold* of peritoneum, which is reflected from the back of the posterior fornix of the vagina on to the front of

FIG. 1249.—The left uterine and ovarian arteries of an unmarried girl of 17½ years. Posterior aspect. (From a preparation by Hamilton Drummond.)



the rectum. It forms the bottom of a deep pouch called the *recto-uterine pouch* which is bounded in front by the posterior wall of the body of the uterus, the supravaginal portion of the cervix uteri and the posterior fornix of the vagina; behind, by the rectum; and laterally, by two crescentic folds of peritoneum which pass backwards from the cervix uteri, one on each side of the rectum, to the posterior wall of the pelvis. These folds are named the *recto-uterine folds*. They contain a considerable amount of fibrous tissue and non-striped muscular fibres, which are attached to the front of the sacrum and constitute the *uterosacral ligaments*.

The *two broad ligaments* (fig. 1240) pass from the margins of the uterus to the lateral walls of the pelvis. Together with the uterus they form a septum across the female pelvis, dividing that cavity into two portions. The anterior part contains the bladder; the posterior part, the rectum, and usually, the terminal coil of the ileum and a part of the pelvic colon.

When the bladder is empty or only slightly distended, the surfaces of the broad ligament are directed upwards and downwards and it has a free anterior and an attached posterior border. As the bladder fills, the plane of the ligament alters and its free border becomes superior in position. In this condition of the

bladder, the broad ligament consists of anterior and posterior layers, which are continuous with each other at its upper, free border, and diverge from each other below, where they reach the Levator ani muscle. The uterine tube is contained in the free border and the adjoining part of the ligament is termed the *mesosalpinx*. The infundibulum of the tube projects from the free border near its lateral extremity. The ovary is attached to the posterior layer by the mesovarium. The portion of the broad ligament which extends from the infundibulum of the tube and the upper pole of the ovary to the lateral wall of the pelvis contains the ovarian blood-vessels, nerves and lymph vessels and is termed the *infundibulopelvic ligament* (suspensory ligament of the ovary). It is continued laterally over the external iliac vessels as a distinct fold. Between the ovary and the uterine tube, the mesosalpinx contains the epoöphoron (p. 1396) and, at its medial end, the paroöphoron (p. 1396) and anastomosing branches of the uterine and ovarian vessels. The uterine artery insinuates itself between the layers of the broad ligament at its inferior border, about 1·5 cm. lateral to the cervix and after it has crossed the ureter (p. 1370). It then ascends in the medial part of the ligament and turns laterally below the uterine tube to anastomose with the ovarian artery. In addition to all the structures already enumerated, the broad ligament encloses the ligament of the ovary (p. 1394), the proximal part of the round ligament of the uterus and some unstriped muscle and fibro-areolar tissue.

The *round ligaments* (fig. 1244) are two narrow, flat bands between 10 cm. and 12 cm. long, situated between the layers of the broad ligament in front of and below the uterine tubes. Commencing at the lateral angle of the uterus each ligament is directed forwards and laterally across the vesical vessels, the obturator vessels and nerve, and the obliterated umbilical artery and over the external iliac vessels. It then passes through the deep (abdominal) inguinal ring, hooking round the commencement of the inferior epigastric artery, and traverses the inguinal canal to reach the labium majus, in which it is lost. The round ligament consists principally of muscular tissue prolonged from the uterus, but also contains some areolar tissue. It is accompanied by blood-vessels, lymph vessels and nerves, and in the fœtus a tubular process of the peritoneum [*processus vaginalis*] is carried with it for a short distance into the inguinal canal. The processus vaginalis is generally obliterated in the adult, but sometimes remains pervious even in advanced life. It corresponds to the processus vaginalis which precedes the descent of the testis.

The round ligament and the ligament of the ovary are together homologous with the gubernaculum testis in the male.

In addition to the ligaments just described, there is a band sometimes named the *ligamentum transversale colli* (Mackenrodt) on each side of the cervix uteri. It is attached to the side of the cervix uteri and to the vault and lateral fornix of the vagina, and is continuous with the fibrous tissue which surrounds the pelvic blood-vessels.

The Vagina (fig. 1245)

The vagina is a canal which extends from the vestibule, or cleft between the labia minora, to the uterus, and is situated behind the bladder and in front of the rectum; it is directed upwards and backwards, its axis forming with that of the uterus an angle of over ninety degrees, opening forwards, but the angle varies with the conditions of the bladder and rectum. Its walls are ordinarily in contact, and the usual shape of its lower part on transverse section is that of an H, the transverse limb being slightly curved forwards or backwards, while the lateral limbs are somewhat convex towards the median plane; its middle part has the appearance of a transverse slit. Its length is 7·5 cm. along its anterior wall, and 9 cm. along its posterior wall; its width gradually increases from below upwards. Its upper end surrounds the vaginal portion of the cervix uteri a short distance from the external os of the uterus, its attachment extending higher on the posterior than on the anterior wall of the uterus. To the recess behind the cervix uteri the term *posterior fornix* is applied, while the smaller recesses at the sides and in front are called the *lateral* and *anterior fornices*.

The *anterior wall* of the vagina is in relation with the fundus of the bladder, and with the urethra. Its *posterior wall*, which is covered with peritoneum in its upper one-fourth, is separated from the rectum by the recto-uterine pouch above, and by some loose fibro-areolar tissue in its middle two-fourths ; the lower one-fourth is separated from the anal canal by a mass of muscular and fibrous tissue, named the *perineal body*. Its sides are enclosed between the Levatores ani muscles (p. 574). As the terminal portions of the ureters pass forwards and medially to reach the fundus of the bladder, they run close to the lateral fornices of the vagina, and as they enter the bladder are usually placed in front of the vagina (p. 1370).

Structure.—The vagina consists of an internal mucous lining and a muscular coat, separated by a layer of erectile tissue.

The *mucous membrane* is firmly fixed to the muscular coat ; on its free surface there are two longitudinal ridges, one on the anterior and the other on the posterior wall of the vagina. These ridges are called the *columns of the vagina*, and from them numerous transverse ridges or rugæ extend laterally on each side. These rugæ are divided by furrows of variable depth, giving to the mucous membrane the appearance of being studded over with conical projections or papillæ ; they are most numerous near the orifice of the vagina, especially before parturition. The epithelium of the mucous membrane is of the stratified squamous variety.

The *muscular coat* consists of two layers : an external longitudinal, which is by far the stronger, and an internal circular layer. The longitudinal fibres are continuous with the superficial muscular fibres of the uterus. The strongest fasciculi are those attached to the rectovesical fascia on each side. The two layers are not distinctly separable from one another. but are connected by oblique decussating fasciculi. In addition to this, the lower end of the vagina is surrounded by a band of striped muscular fibres, termed the *Bulbospongiosus* (p. 581).

External to the muscular coat there is a layer of areolar tissue, containing a large plexus of blood-vessels.

The *erectile tissue* is situated between the mucous membrane and the muscular coat ; it consists of a layer of loose areolar tissue, which contains a plexus of large veins, and numerous bundles of unstriped muscular fibres, derived from the circular muscular layer. The arrangement of the veins is similar to that found in other erectile tissues.

Vessels and Nerves.—The *arteries* of the vagina are derived from the vaginal, uterine, internal pudendal, and middle rectal branches of the internal iliac arteries (pp. 777 to 781). The *veins* form plexuses at the sides of the vagina, and these plexuses are drained through the vaginal veins into the internal iliac veins. The *lymph vessels* are described on p. 875. The *nerves* are derived from the vaginal plexuses, and from the pelvic splanchnic nerves.

The External Genital Organs of the Female (fig. 1250)

The **external genital organs of the female** [pudendum muliebre] are : the mons pubis, the labia majora et minora pudendi, the clitoris, the vestibule of the vagina, the bulb of the vestibule and the greater vestibular glands. The term *pudendum* or *vulva*, as generally applied, includes all these parts.

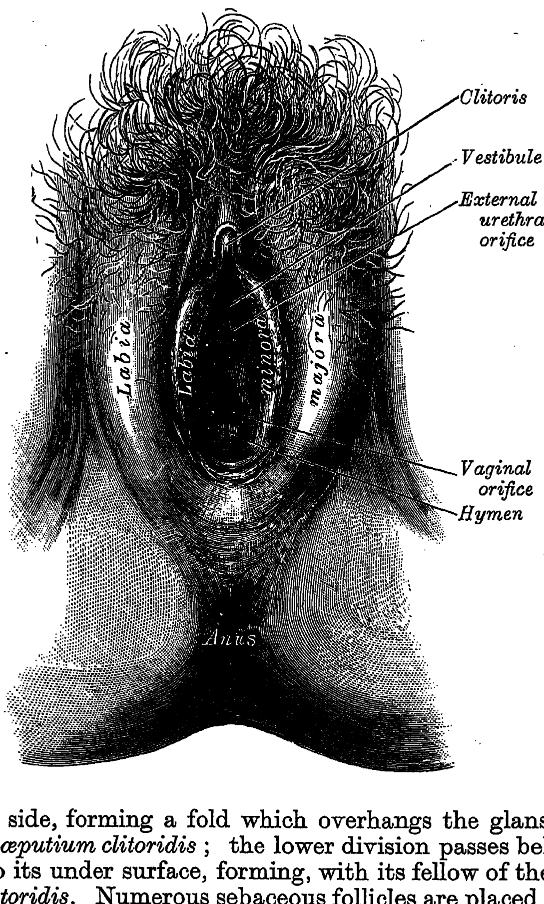
The **mons pubis**, the rounded eminence in front of the pubic symphysis, is formed by a collection of fatty tissue beneath the skin. It becomes covered with hair at the time of puberty over an area which has a horizontal upper limit, whereas in the male the pubic hair extends upwards towards the umbilicus in and near the median plane.

The **labia majora** are two prominent, longitudinal, cutaneous folds which extend downwards and backwards from the mons pubis, and form the lateral boundaries of a fissure or cleft, named the *pudendal cleft*, into which the vagina and urethra open. Each labium has two surfaces, an outer, pigmented and covered with crisp hairs ; and an inner, smooth and beset with large sebaceous follicles. Between the two surfaces there is a considerable quantity of areolar tissue, fat, and a tissue resembling the dartos muscle of the scrotum, besides vessels, nerves and glands. The labia are thicker in front, where they form by their meeting the *anterior commissure*. Posteriorly they are not really joined, but appear to become lost in the neighbouring integument, ending close to,

and nearly parallel with, each other; together with the connecting skin between them, they form the *posterior commissure,* or posterior boundary of the pudendum. The interval between the posterior commissure and the anus, from 2·5 cm. to 3 cm. in length, constitutes the gynæcological perineum.

The **labia minora** are two small cutaneous folds, situated between the labia majora, and extending from the clitoris obliquely downwards, laterally and backwards for about 4 cm. on each side of the orifice of the vagina, between which and the labia majora they end; in the virgin the posterior ends of the labia minora are usually joined across the median plane by a fold of skin, named the *frenulum of the labia.* Anteriorly, each labium minus divides into two portions; the upper division passes above the clitoris to meet its fellow

Fig. 1250.—The external genital organs of the female. The labia have been drawn apart.



of the opposite side, forming a fold which overhangs the glans clitoridis and is named the *præputium clitoridis*; the lower division passes below the clitoris and is united to its under surface, forming, with its fellow of the opposite side, the *frenulum clitoridis.* Numerous sebaceous follicles are placed on the opposed surfaces of the labia minora.

The **vestibule.**—The cleft between the labia minora is named the *vestibule of the vagina*: in it the vaginal and external urethral orifices are situated, and, between them, numerous small mucous glands, termed the *lesser vestibular glands,* open on the surface of the vestibule. The part of the vestibule between the vaginal orifice and the frenulum of the labia minora consists of a shallow depression named the *vestibular fossa.*

The **clitoris** is an erectile structure, homologous with the penis. It is situated caudal to the anterior commissure, partially hidden between the anterior ends of the labia minora. The *body of the clitoris* consists of two corpora cavernosa, composed of erectile tissue enclosed in a dense layer of fibrous membrane, and separated along their medial surfaces by an incomplete fibrous

pectiniform septum ; each corpus cavernosum is connected to the pubic and ischial rami by a *crus*. The free extremity, or *glans clitoridis*, is a small rounded tubercle, consisting of spongy erectile tissue, and highly sensitive. The clitoris is provided, like the penis, with a suspensory ligament, and with two small muscles, named the Ischiocavernosi (p. 581), which are inserted into the crura of the clitoris.

The **vaginal orifice** is a median slit below and behind the opening of the urethra ; its size varies inversely with that of the *hymen.*

The **hymen vaginæ** is a thin fold of mucous membrane situated at the orifice of the vagina ; the inner surfaces of the fold are normally in contact with each other, and the vaginal orifice appears as a cleft between them. The hymen varies much in shape. When stretched, its commonest form is that of a ring, generally broadest posteriorly ; sometimes it is represented by a semilunar fold, with its concave margin turned towards the pubes. Occasionally it is cribriform or its free margin forms a membranous fringe. It may be entirely absent, or may form a complete septum across the lower end of the vagina ; the latter condition is known as an imperforate hymen. When the hymen has been ruptured, small rounded elevations known as the *carunculæ hymenales* are found as its remains.

The **external urethral orifice** is placed about 2·5 cm. behind the glans clitoridis and immediately in front of the orifice of the vagina : it usually assumes the form of a short, sagittal cleft with slightly raised margins.

The **bulb of the vestibule** is the homologue of the bulb of the penis and adjoining part of the corpus spongiosum penis of the male, and consists of two elongated masses of erectile tissue, placed one on each side of the vaginal orifice and united to each other in front by a narrow median band termed the *commissura bulborum* (pars intermedia). Each lateral mass measures about 3 cm. in length. Their posterior ends are expanded and are in contact with the greater vestibular glands ; their anterior ends are tapered and joined to one another by the commissure ; their deep surfaces are in contact with the perineal membrane ; superficially they are covered with the Bulbospongiosus.

The **greater vestibular glands** are the homologues of the bulbo-urethral glands in the male. They consist of two small, round, or oval, bodies of a reddish-yellow colour, situated one on each side of the vaginal orifice, in contact with the posterior end of the lateral mass of the bulb of the vestibule. Each gland opens by means of a duct, about 2 cm. long, immediately lateral to the hymen, in the groove between its attached border and the labium minus.

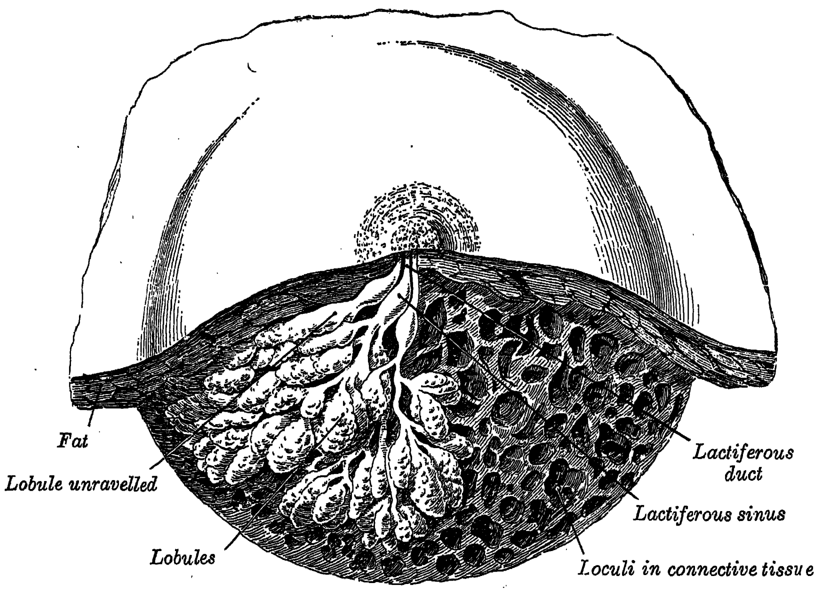
The Mammary Glands (figs. 1251, 1252)

The **mammary glands** secrete the milk, and are accessory glands of the generative system. They exist in the male as well as in the female, but in the former only in the rudimentary state. In the female they are two large, hemispherical eminences lying within the superficial fascia on the front and sides of the chest ; each extends vertically from the second rib to the sixth rib, and, transversely, at the level of the fourth costal cartilage, from the side of the sternum to near the mid-axillary line. In weight and size they differ at different periods of life, and in different individuals. Before puberty they are small, but they enlarge as the generative organs become more completely developed. They increase during pregnancy, and especially during lactation, and become atrophied in old age. The deep surface of each is flattened, or slightly concave, and irregularly circular in outline, its longest diameter being directly upwards and laterally towards the axilla ; it is separated from the fascia covering the Pectoralis major, Serratus anterior and Obliquus externus abdominis by loose areolar tissue. The subcutaneous surface of the mammary gland is convex, and presents, just below the centre, a small conical prominence, named the *nipple.*

The **nipple** is a cylindrical or conical eminence situated about the level of the fourth intercostal space. It is capable of undergoing a sort of erection from mechanical excitement, a change mainly due to the contraction of its muscular

fibres. It is of a pink or brownish hue, and its surface is wrinkled and provided with secondary papillæ; it is perforated by from fifteen to twenty orifices, the apertures of the lactiferous ducts. The base of the nipple is encircled by a coloured area of skin called the *areola*. In the virgin the areola is of a delicate rosy hue; about the second month of pregnancy it enlarges and acquires a darker tinge, and as pregnancy advances it may assume a dark brown, or even black colour. This colour diminishes as soon as lactation is over, but is never lost entirely. These changes in the colour of the areola are of importance in forming a conclusion in a case of suspected first pregnancy. Near the base of the nipple, and upon the surface of the areola, there are numerous sebaceous glands, termed the *areolar glands*, which become much enlarged during lactation and present the appearance of small tubercles beneath the skin; they secrete

Fig. 1251.—A dissection of the lower half of the mammary gland during the period of lactation. (Luschka.)



a peculiar fatty substance, which serves as a protection to the skin of the nipple. The nipple is traversed by the ducts of the gland, and, in addition, contains numerous vessels, intermixed with plain muscular fibres, which are principally arranged in a circular manner around the base, but a few fibres radiate from base to apex.

Structure (figs. 1251 to 1253).—The mammary gland consists (*a*) of gland-tissue; (*b*) of fibrous tissue, connecting its lobes; and (*c*) of fatty tissue in the intervals between the lobes. The subcutaneous tissue encloses the gland and sends numerous septa into it to support its various lobules. From that part of the fascia which covers the gland fibrous processes pass forwards to the skin and the nipple; these were named by Sir Astley Cooper the *ligamenta suspensoria*. The gland-tissue is of a pale reddish colour, firm in texture, and forms a lobulated mass which is flattened from before backwards and thicker in the centre than at the circumference. It consists of numerous lobes, and these are composed of lobules, connected together by areolar tissue, blood-vessels and ducts. The smallest lobules consist of a cluster of rounded alveoli which open into the smallest branches of the lactiferous ducts; these branches unite to form larger ducts which end in the excretory ducts or *ductus lactiferi*. The lactiferous ducts vary from fifteen to twenty in number; they converge towards the areola, beneath which they form dilatations, named *lactiferous sinuses*, which serve as reservoirs for the milk. At the base of the nipple they become contracted, and pursue a straight course to its summit, perforating it by separate orifices considerably narrower than the ducts themselves. The ducts are composed of areolar tissue containing longitudinal and transverse elastic fibres; they are lined by columnar epithelium resting on a basement-membrane. The epithelium of the alveoli differs according to

the state of activity of the organ. In the gland of a woman who is not pregnant or suckling, the alveoli are very small and solid, being filled with a mass of granular polyhedral cells. During pregnancy the alveoli enlarge, and the cells undergo rapid multiplication. At the commencement of lactation, the cells in the centre of the alveolus undergo fatty degeneration, and are eliminated in the first milk, as *colostrum corpuscles*. The peripheral cells of the alveolus remain, and form a single layer of granular, short columnar cells, with spherical nuclei, lining the basement membrane. When the gland is active, oil globules are found in the alveolar cells and are discharged into the lumen, constituting the milk-globules. When the acini are distended by the accumulation of the secretion the lining epithelium becomes flattened.

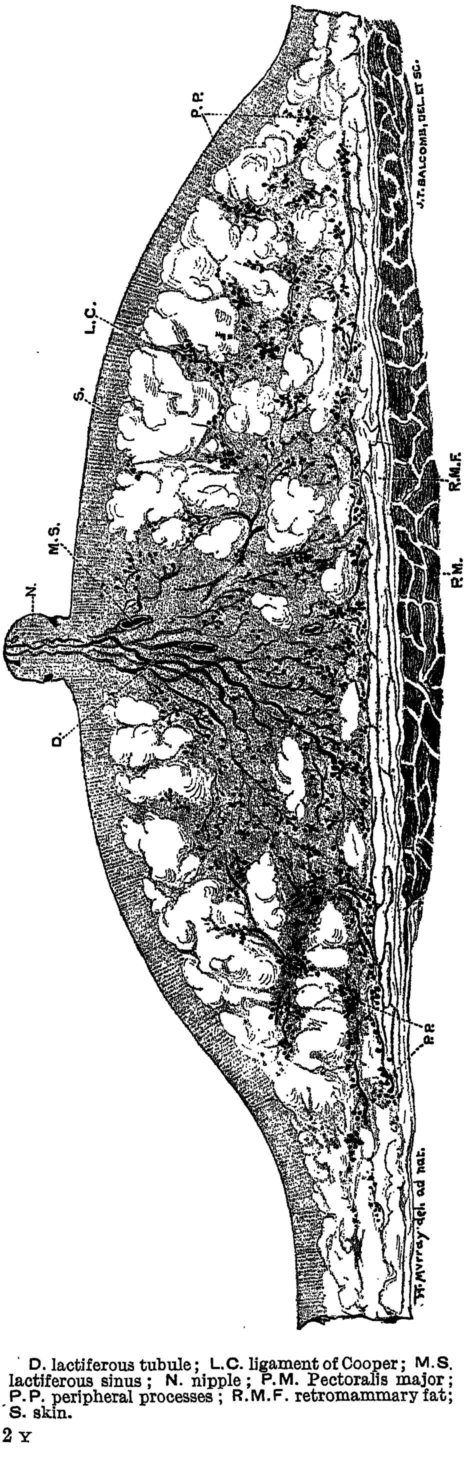
The *fibrous tissue* invests the entire surface of the mammary gland, and sends down septa between its lobes, connecting them together.

The *fatty tissue* covers the surface of the gland, and occupies the intervals between its lobes. It usually exists in considerable abundance, and determines the form and size of the gland. There is no fat immediately beneath the areola and nipple.

Vessels and Nerves.—The *arteries* supplying the mammary gland are derived from the thoracic branches of the axillary artery, and from the internal mammary and intercostal arteries. The *veins* describe an anastomotic circle round the base of the nipple, called by Haller the *circulus venosus*. From this circle, branches transmit the blood to the circumference of the gland, and end in the axillary and internal mammary veins. The *lymph vessels* are described on p. 861. The *nerves* are derived from the anterior and lateral cutaneous branches of the fourth, fifth, and sixth thoracic nerves.

Applied Anatomy.—The ducts descending from the nipple radiate through the gland, and when an incision is made into the breast the scalpel should be directed radially, from the centre to the periphery, so that it may not pass across the ducts. A milk duct may become obstructed and distended, forming a cyst known as a galactocele. Abscess frequently occurs about the mammary gland, more often in women who are lactating, especially in those who have cracks and fissures about the nipple. The abscess may be between the septa, in the gland-tissue itself, or it may lie beneath the skin by the side of the nipple and superficial to the gland, or it may form beneath the gland, between it and the deep fascia. Free incision, radiating from the nipple, is required in such cases.

Fig. 1252.—Horizontal section of the mammary gland at the level of the nipple in a multiparous female, aged forty years. (Stiles.) (From Quain's *Anatomy*, vol. iii. part iv.)

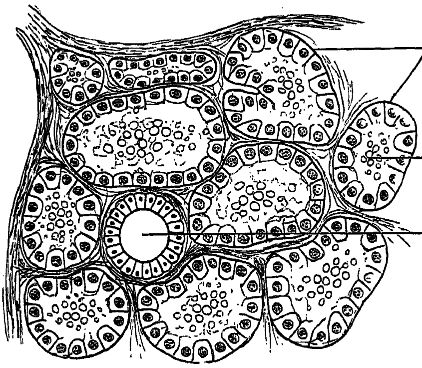


D. lactiferous tubule; L.C. ligament of Cooper; M.S. lactiferous sinus; N. nipple; P.M. Pectoralis major; P.P. peripheral processes; R.M.F. retromammary fat; S. skin.

Cystic formation of many different kinds is commonly seen in the mammary gland ; in some cases it is due to dilatation of the larger ducts or of the lymph-spaces throughout the gland ; in others the cysts occur in new growths of the gland, or as the result of obstruction of the smaller ducts by chronic inflammatory processes.

Malignant growths are seen more often in the mammary gland than in any other organ. A hard, contracting tumour-mass results, which drags on the fibrous septa between the

FIG. 1253.—A section through a portion of the non-lactating mammary gland.



lobes so that fixation or retraction of the nipple ensues, and sooner or later the malignant infiltration invades the surrounding gland-tissues, the skin, the deep fascia and Pectorales, and even the chest wall and pleura. The lymph glands beneath the Pectorales and those situated towards the apex of the axilla become involved early with secondary malignant deposit, and later the supraclavicular glands enlarge. In other cases the mediastinal glands may be involved, when the disease is situated on the medial side of the nipple.

The operation for removal of a mammary gland affected with malignant disease should be an extensive procedure, with the object of extirpating all fascial planes and lymphatic structures that may become infected.

THE DUCTLESS GLANDS

All animals possess a number of glands the secretions of which exercise an important influence on general metabolic processes, including growth. In order that they may be able to act in this way, the secretions are passed directly from the secreting cells into the blood-stream as it circulates through the capillaries of the glands, and so are carried to all parts of the body. Groups of cells in some of the other glands in the body have a similar function, although they do not constitute distinct anatomical entities. The cell-islets of the pancreas, and the interstitial cells of the testes and ovaries pass their secretions directly into the blood-stream and exert their functions in a similar manner. Glands or groups of cells which produce such internal secretions are collectively known as *endocrine organs*.

Despite the great output of literature dealing with the subject, it is still impossible to group the endocrine organs on a functional basis, and it is doubtful whether much benefit is to be derived from utilising any other basis. It may, however, prove convenient to group the hypophysis cerebri and the pineal body together, owing to their direct ectodermal origin. In the same way, the thyroid and parathyroid glands may be grouped together, as they are both derived from the pharyngeal entoderm (p. 165). The paraganglia, the medulla of the suprarenal gland, the glomera carotica and the glomus coccygeum are all (with the possible exception of the last-named) derived from primitive sympathochromaffin cell-groups (p. 108), and, therefore, indirectly ectodermal in origin. Lastly, the cortex of the suprarenal gland is developed from the cœlomic epithelium, so that it may be referred to the mesoderm.

In addition, the term ' ductless glands ' applies with equal truth to a number of glands or glandular bodies which are principally concerned with the replacement and destruction of the corpuscles of the blood and lymph. The lymph glands, the spleen and, probably, the thymus * belong to this category.

For convenience, all the ductless glands are dealt with in this section with the exceptions of the hypophysis cerebri (p. 964), the pineal body (p. 961) and the lymph glands (pp. 844 to 879), which have already been described. The following, however, have still to be considered:

The Thyroid gland.
The Parathyroid glands.
The Paraganglia.
The Suprarenal glands.
The Carotid bodies.
The Coccygeal body.
The Thymus.
The Spleen.

The Thyroid Gland (fig. 1254)

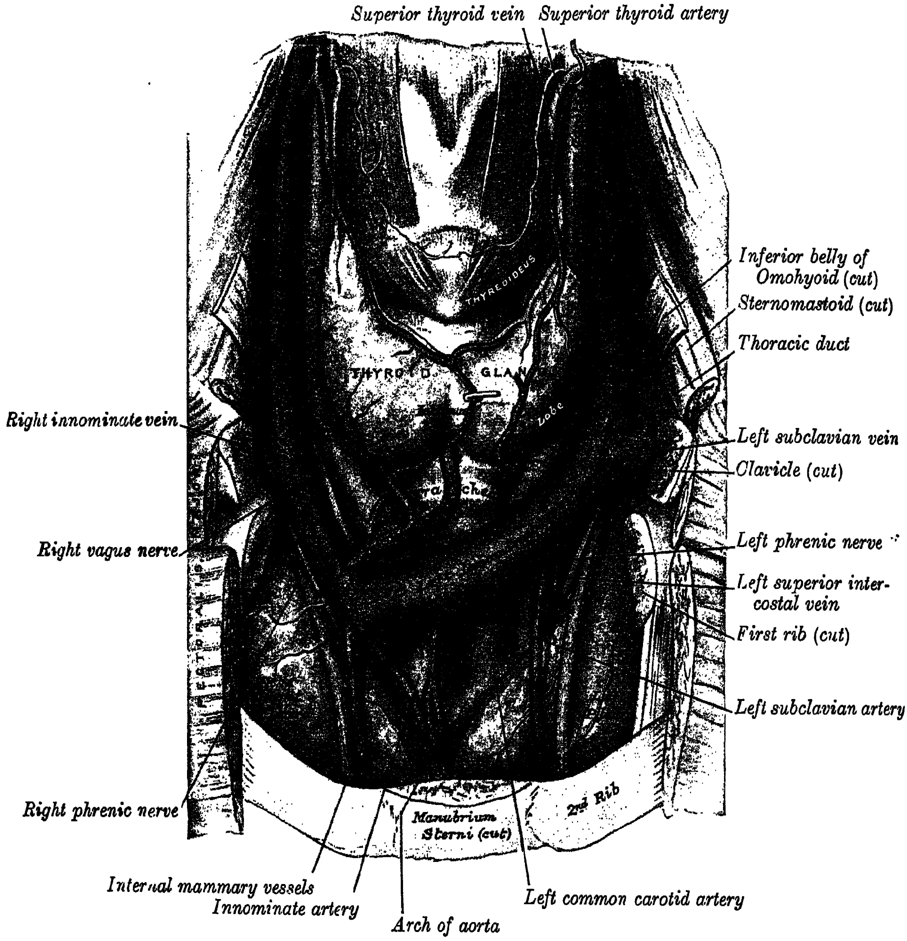
The **thyroid gland** is a highly vascular organ, situated at the front and sides of the lower part of the neck, opposite the fifth, sixth and seventh cervical vertebræ. It is ensheathed by the pretracheal layer of the deep cervical fascia (fig. 584), and consists of right and left lobes connected across the median plane by a narrow portion, termed the *isthmus*. Its weight is somewhat variable, but is usually about 30 gm. It is slightly heavier in the female, in whom it becomes enlarged during menstruation and pregnancy.

The *lobes* are conical in shape, the apex of each being directed upwards and laterally as far as the junction of the middle with the lower one-third of the thyroid cartilage; the base is on a level with the fifth or sixth tracheal ring. Each lobe is about 5 cm. long; its greatest width is about 3 cm., and its thick-

* Sir E. Sharpey-Schafer (*The Endocrine Organs*, 2nd edition) is of the opinion that the thymus should not be classed as an endocrine organ.

ness about 2 cm. The posteromedial part of each lobe is attached to the side of the cricoid cartilage by a ligamentous band. The *lateral*, or *superficial*, *surface* is convex. Outside the sheath of pretracheal fascia, this surface is closely covered with the Sternothyroid and it is the insertion of this muscle into the oblique line on the lamina of the thyroid cartilage which prevents the upper part of the lobe from extending forwards on to the Thyrohyoid muscle. More superficially, this surface is covered with the Sternohyoid and the upper belly of the Omohyoid muscle, overlapped below by the anterior border of the Sternomastoid. The remaining superficial relations are formed by the deep and

FIG. 1254.—Dissection of the lower part of the neck, and the upper part of the thorax. Anterior aspect.

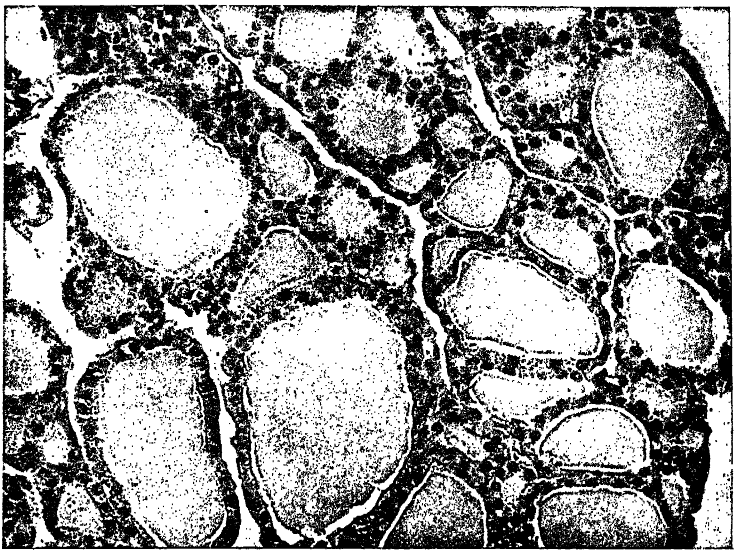


superficial fasciæ and the skin. The *medial surface* is moulded over the larynx and trachea. Above, it is in contact with the Inferior constrictor of the pharynx and the posterior part of the Cricothyroid muscle, which intervene between the gland and the posterior part of the lamina of the thyroid and the side of the cricoid cartilage. The external laryngeal nerve passes deep to this part of the gland on its way to the Cricothyroid muscle. Below, it is related to the side of the trachea, in front, and to the recurrent laryngeal nerve and (particularly on the left side) to the œsophagus, behind. The *posterior*, or *posterolateral*, *surface* is related to the carotid sheath and overlaps the common carotid artery. The *anterior border*, which is closely related to the anterior branch of the superior thyroid artery, is thin and inclines obliquely from above downwards and medially. The *posterior border*, which is blunt and rounded, intervenes between the posterior and the medial surfaces and is closely related below to the inferior

thyroid artery and an anastomosing branch which connects that vessel to the posterior branch of the superior thyroid artery. In addition the parathyroid glands are related to this border, although they may be found in association with the posterior surface.

The *isthmus* connects together the lower parts of the two lobes ; it measures about 1·25 cm. transversely, and the same vertically, and usually covers the second, third and fourth rings of the trachea. Its situation and size present, however, many variations. It is covered with the skin and fascia, and close to the median plane, on each side, with the Sternothyroid. An anastomotic branch uniting the two superior thyroid arteries runs along its upper border ; at its lower border the inferior thyroid veins leave the gland. Sometimes the isthmus is altogether wanting.

FIG. 1255.—Section of thyroid gland of cat. (E. Sharpey-Schafer.) ×400. Photograph. (From Sharpey-Schafer's *Essentials of Histology.*)



The vesicles are occupied by colloid, which has partly shrunk away from the epithelium.

A third lobe, of conical shape, called the *pyramidal lobe*, frequently extends from the upper part of the isthmus, or from the adjacent portion of either lobe, but most commonly the left, to the hyoid bone. It is occasionally quite detached, or may be divided into two or more parts.

A fibrous or muscular band is sometimes attached, above, to the body of the hyoid bone, and below, to the isthmus of the gland, or its pyramidal lobe ; when muscular, it is termed the *Levator glandulæ thyreoideæ.*

Small detached portions of thyroid tissue are sometimes found in the vicinity of the lobes or above the isthmus ; they are called *accessory thyroid glands.*

Structure.—The thyroid gland is closely invested by a thin capsule of connective tissue, which sends incomplete septa into its substance, dividing it into masses of irregular form and size. The gland is of a brownish-red colour, and is made up of a number of closed vesicles, just visible to the naked eye, containing a yellow, glairy fluid, and separated from each other by intermediate connective tissue (fig. 1255). The vesicles are arranged in groups or gland-units, each unit being enclosed in an endothelial lymph-sac.

The vesicles of the thyroid of the adult are generally closed spherical sacs ; but in some young animals (e.g. dogs) they are more or less tubular and branched. Each is lined with a single layer of cubical epithelium. There does not appear to be a basement-membrane, so that the epithelial cells are in direct contact with the connective tissue reticulum. The vesicles are of various sizes, and contain a viscid, homogeneous, semi-fluid, slightly yellowish, colloid material ; red blood-corpuscles are found in various stages of disintegration and decolorisation, the yellow tinge being probably due to hæmoglobin, which is set free from the corpuscles. The colloid material contains an iodine compound, *thyroxin* or *iodothyro-*

globulin, and, when coagulated by hardening reagents, is readily stained by eosin and other dyes. It passes out between the cubical cells and is absorbed into the blood or lymph.

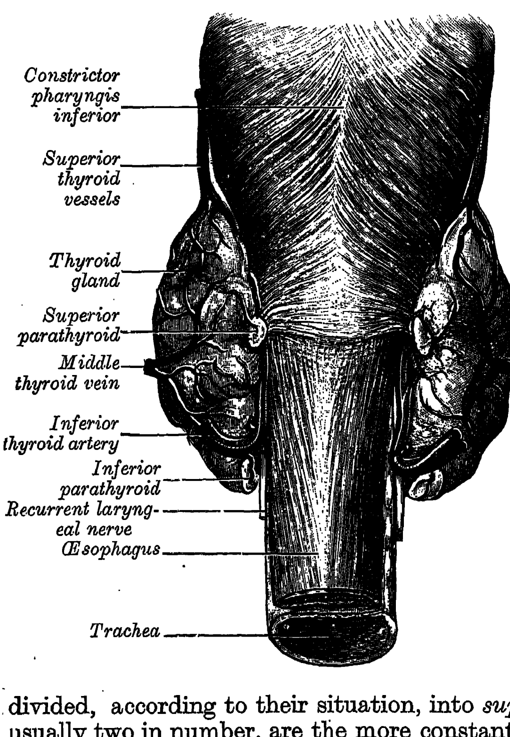
Vessels and Nerves.—The *arteries* supplying the thyroid gland are the superior (p. 704) and inferior thyroid arteries (p. 737); sometimes there is an additional branch (a. thyreoidea ima) from the innominate artery or the arch of the aorta, which ascends upon the front of the trachea. The arteries are remarkable for their large size and frequent anastomoses. The *veins* form a plexus on the surface of the gland and on the front of the trachea; from this plexus the superior, middle and inferior thyroid veins arise; the superior and middle end in the internal jugular vein, the inferior in the innominate vein. The capillary blood-vessels form a dense plexus in the connective tissue around the vesicles, between the epithelium of the vesicles and the endothelium of the lymph vessels which surround a greater or smaller part of the circumference of the vesicle. The *lymph vessels* run in the interlobular connective tissue, not uncommonly surrounding the arteries which they accompany and communicate with a network in the capsule of the gland; they may contain colloid material. They end in the thoracic duct and the right lymphatic duct. The *nerves* are derived from the middle and inferior cervical ganglia of the sympathetic.

G. Scott Williamson * states there is a free anastomosis between the branches of the superior thyroid arteries and the larger surface veins of the gland. He also describes a very definite system of lymph vessels which leaves each lobe at the point of entrance of the branches of the inferior thyroid artery, and passes directly into the lymph-spaces of the lobes of the thymus.

Applied Anatomy.—Any enlargement of the thyroid gland is called a goitre. When a goitre continues to grow, and especially when there are commencing symptoms of tracheal pressure, operative interference becomes necessary.

Partial extirpation of the thyroid, viz. the removal of one lobe with division of the isthmus, may be required in cases of parenchymatous goitre, and in the diffuse form of adenomatous disease. It is a more radical proceeding, and carries with it a much greater risk of hæmorrhage; there is also a danger of wounding the recurrent laryngeal nerve. The whole gland must never be removed, as such a procedure is followed by the development of myxœdema. In dealing with the inferior thyroid artery, the position of the recurrent laryngeal nerve (p. 737) must be borne in mind, lest it should be ligatured or divided. Temporary aphonia not uncommonly follows from bruising of the nerve, and if nothing more serious has occurred soon passes off.

FIG. 1256.—The parathyroid glands. Posterior aspect.



THE PARATHYROID GLANDS

The parathyroid glands (fig. 1256) are small, brownish-red bodies, situated as a rule between the posterior borders of the lobes of the thyroid gland and its capsule. They measure on an average about 6 mm. in length, and from 3 mm. to 4 mm. in breadth, and usually present the appearance of flattened oval discs. They are divided, according to their situation, into *superior* and *inferior*. The superior, usually two in number, are the more constant in position, and are situated one on each side, at the level of the lower border of the cricoid cartilage, behind the junction of the pharynx and œsophagus. The inferior, also usually two in number, may be applied to the lower edges of the lobes of the thyroid gland, or may be placed at some little distance below the thyroid gland, or in

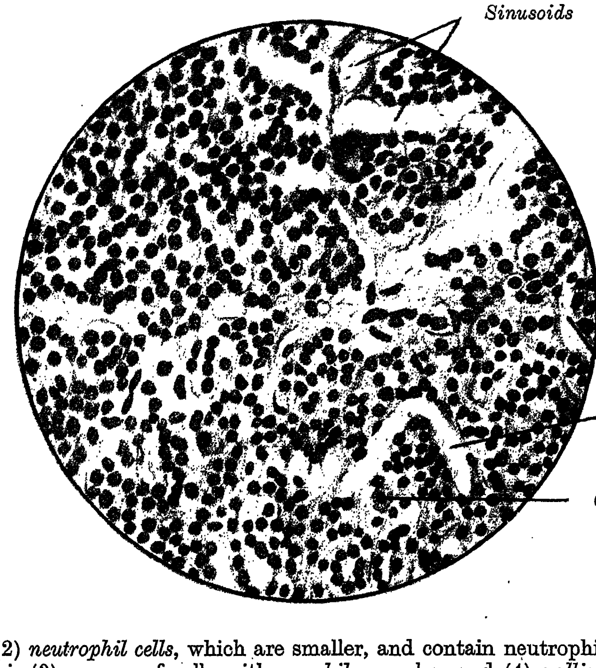
* Arris and Gale lecture on "The Applied Anatomy and Physiology of the Thyroid Apparatus" (*British Journal of Surgery*, January 1926, page 466).

relation to one of the inferior thyroid veins. * According to Walton, † the inferior parathyroid is found as a rule in one of three positions : (1) within the fascial sheath of the thyroid gland, below the inferior thyroid artery and near the lower pole of the lobe : (2) posterior to the fascial sheath of the thyroid gland, immediately above the inferior thyroid artery : and (3) within the substance of the lobe of the thyroid gland near the lower end of its posterior border.

In man, they number four as a rule ; fewer than four were found in less than 1 per cent. of over a thousand persons (Pepere ‡), but more than four in over 33 per cent. of 122 bodies examined by Civalleri. In addition numerous, minute islands of parathyroid tissue may be found scattered in the connective tissue and fat of the neck round the parathyroid glands proper, and quite distinct from them.

Structure.—Microscopically the parathyroid glands consist of intercommunicating columns of cells supported by connective tissue containing a rich supply of blood-capillaries (sinusoids). Four types of cells have been described: (1) *principal cells*, large, clear and polygonal, with distinct cell outlines and dark nuclei which show a definite chromatin

FIG. 1257.—A section of a human parathyroid gland. Stained with hæmatoxylin and eosin. ×400.



network, (2) *neutrophil cells*, which are smaller, and contain neutrophil granules and very dark nuclei, (3) groups of cells with *oxyphil* granules, and (4) *pallisade cells*, which are principal cells forming a pallisade on the borders of the sinusoids (fig. 1257). Vesicles containing colloid are sometimes found.

Vessels and Nerves.—The parathyroid glands receive a very rich *blood-supply* from the inferior thyroid arteries or from the anastomoses between the superior and inferior thyroid arteries. Their *lymph* vessels are numerous, and are associated with those of the thyroid and thymus glands. Their *nerve-supply* is derived from the sympathetic, either directly from the superior or middle cervical ganglia, or indirectly through a plexus in the fascia on the posterior surface of the lobes of the thyroid gland.

The Paraganglia

The paraganglia are found in two chief groupings : (1) as small masses of chromaffin cells (p. 124) placed either within the capsules of the sympathetic ganglia or in close contact with them ; (2) as small groups of chromaffin cells scattered throughout the sympathetic plexuses. The two largest masses in this latter group are the aortic bodies.

* Consult an article by D. A. Welsh, *Journal of Anatomy and Physiology*, vol. xxxii.

† A. James Walton, *British Journal of Surgery*, vol. xix. 1931-32.

‡ Consult *Le Ghiandole paratiroidee*, by A. Pepere, Turin, 1906.

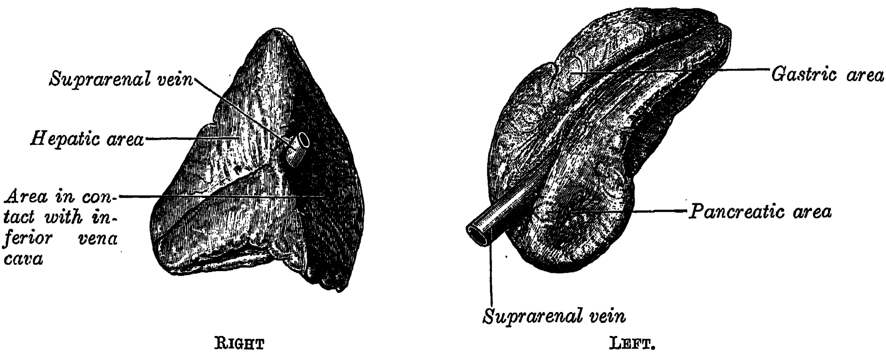
The *aortic bodies* are two small brownish-coloured bodies which lie one on each side of the abdominal aorta at the level of the origin of the inferior mesenteric artery, in intimate relationship with the abdominal aortic plexus of the sympathetic. They are of considerable size (8-10 mm. long) in the new-born child, and may be united to one another across the front of the abdominal aorta. After birth they gradually atrophy, and they become invisible to the naked eye shortly after puberty.

Structure.—The aortic bodies consist of masses of polygonal or cubical epithelium, imbedded in a wide-meshed capillary plexus. The cell-bodies stain brown or yellow when treated with chromic salts.

The Suprarenal Glands (figs. 1258, 1259)

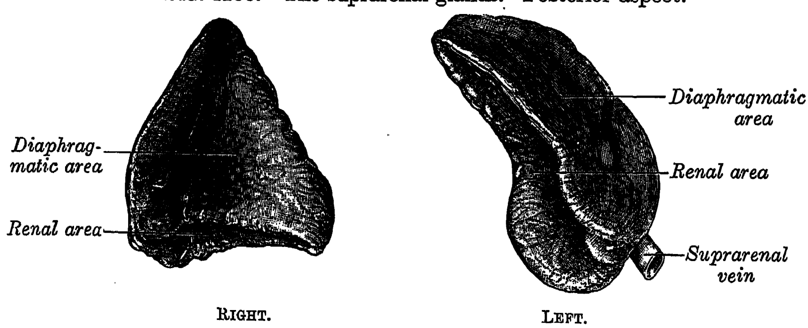
The **suprarenal glands** are two small, flattened bodies of a yellowish colour, situated, one on each side of the median plane, at the posterior part of the abdomen, behind the peritoneum, and immediately above and in front of the upper end of the kidney. They are surrounded by areolar tissue containing a

Fig. 1258.—The suprarenal glands. Anterior aspect.



considerable amount of fat. Each gland consists of an outer cortical portion, which is rich in lipoids and contains no chromaffin tissue, and an inner medullary portion, which stains deeply with chromic salts. It would appear that the two parts of the gland are functionally distinct from each other, although even that is not yet certain. They are derived from different sources in the embryo

Fig. 1259.—The suprarenal glands. Posterior aspect.



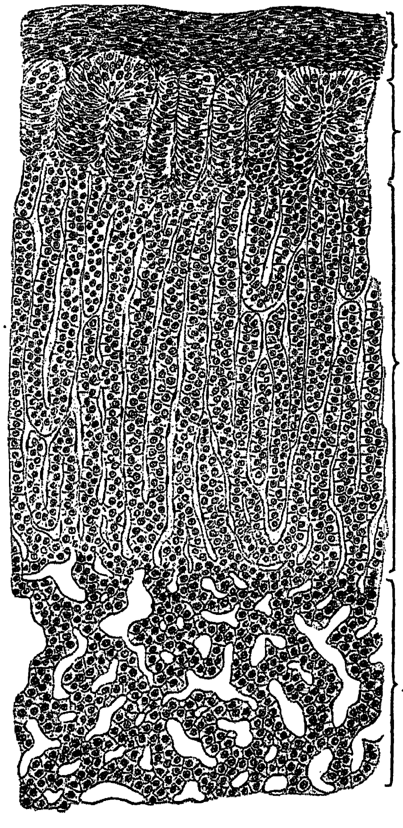
(p. 125) and in many fishes they exist as separate entities. In man it is not uncommon to find small masses of tissue, identical with the suprarenal cortex, in the neighbourhood of the gland or in other situations. They are termed 'cortical bodies.' Ontogenetically, phylogenetically, structurally, and, probably, functionally, the cortex and the medulla of the suprarenal gland are distinct from each other, but anatomically they constitute a single entity and are therefore described as such in this section.

The right gland is somewhat pyramidal in shape, bearing a resemblance to

a cocked hat; the left is semilunar, and is usually larger and extends to a higher level than the right. They measure from 30 mm. to 50 mm. in height; about 30 mm. in breadth, and from 4 mm. to 6 mm. in thickness. The average weight of each is from 3 gm. to 4 gm.

Relations.—The *right suprarenal gland* is situated behind the inferior vena cava and the right lobe of the liver, and in front of the Diaphragm and upper end of the right kidney. It is roughly triangular in shape; its base, usually directed downwards, is in contact with the medial and anterior surfaces of the upper end of the right kidney. Frequently the base is related to the upper part of the medial border of the right kidney and not to its upper pole. Its *anterior surface* looks forwards and laterally, and has two areas: a medial, narrow and non-peritoneal, which lies behind the inferior vena cava; and a lateral, somewhat triangular, in contact with the liver. The upper part of the latter surface is devoid of peritoneum, and is in relation with the lower and medial angle of the bare area of the liver, while its inferior portion may be covered by peritoneum, reflected on to it from the inferior layer of the coronary ligament; occasionally the duodenum overlaps the inferior portion. A little below the apex, and near the anterior border of the gland, there is a short furrow termed the hilum, from which the right suprarenal vein emerges to join the inferior vena cava. Its *posterior surface* is divided into upper and lower parts by a curved ridge; the upper, slightly convex, rests upon the Diaphragm; the lower, concave, is in contact with the upper end and the adjacent part of the anterior surface of the right kidney. The thin *medial border* of the gland is related to the right coeliac ganglion, which lies medial to its lower part, and to the right (inferior) phrenic artery, as the vessel courses upwards and laterally on the right crus of the Diaphragm.

Fig. 1260.—Vertical section of cortex of suprarenal gland of dog. (Böhm and V. Davidoff.) (From Sharpey-Schafer's *Essentials of Histology*.)



The *left suprarenal gland* is crescentic in shape, its concavity being adapted to the medial border of the upper part of the left kidney. Its medial border is convex, its lateral concave; its upper end is narrow, its lower rounded. Its *anterior surface* has two areas: an upper, covered with the peritoneum of the lesser sac, which separates it from the cardiac end of the stomach and sometimes from the superior extremity of the spleen; and a lower, which is not covered with peritoneum, but is in contact with the pancreas and splenic artery. The hilum, which is directed downwards and forwards, is placed near the lower part of the anterior surface. From it the left suprarenal vein emerges to join the left renal vein. Its *posterior surface* is divided into two areas by a ridge; the lateral area rests on the kidney, the medial and smaller, on the left crus of the Diaphragm. The convex *medial border* is related to the left cœliac ganglion, which lies medial to its lower part, and to the left phrenic and left gastric arteries, as they run upwards on the left crus of the Diaphragm.

Small *accessory suprarenal* glands are often found in the areolar tissue round the suprarenal glands; they are sometimes present in the spermatic cord and epididymis, and in the broad ligament of the uterus.

Structure.—The suprarenal gland is closely invested by a capsule of fibro-areolar tissue from which trabeculæ pass into the substance of the gland; the capsule may contain smooth muscular fibres. On section, the gland is seen to consist of two portions (fig. 1260): an external, the cortex, and an internal, the medulla. The cortex constitutes the larger part of the organ, and is of a deep yellow colour; the medulla is soft, pulpy and of a dark red or brown colour.

The *cortex* (fig. 1260) consists of a fine connective tissue network, in which is imbedded the glandular epithelium. The epithelial cells are polyhedral in shape and possess rounded nuclei; many of the cells contain coarse granules, others lipoid globules. Owing to the differences in the arrangement of the cells three distinct zones can be made out: (1) The *zona glomerulosa*, situated beneath the capsule, consists of cells arranged in rounded groups, with here and there indications of an alveolar structure. (2) The *zona fasciculata*, continuous with the zona glomerulosa, is composed of columns of cells arranged in a radial manner; these cells contain fine granules and in many instances globules of lipoid material. (3) The *zona reticularis*, in contact with the medulla, consists of cylindrical columns of cells irregularly arranged; these cells often contain pigment-granules which give this zone a darker appearance than the rest of the cortex.

The *medulla* is extremely vascular, and is composed of a mass of large, finely granular chromaffin cells, permeated by venous sinusoids. This portion of the gland is richly supplied with non-medullated nerve-fibres, and here and there sympathetic ganglion cells are found.

The suprarenal gland is large in the fœtus, owing to the great development of the inner layer of the cortex. This layer has been named the *boundary zone* by Elliott and Armour. Its cells contain no lipoid granules. This zone disappears soon after birth and is absent in anencephalic fœtuses.

In connexion with the development of the medulla from the sympathochromaffin tissue, it is to be noted that this portion of the gland secretes a substance, named *adrenalin*, which has the property of stimulating all sympathetic nerve-endings.

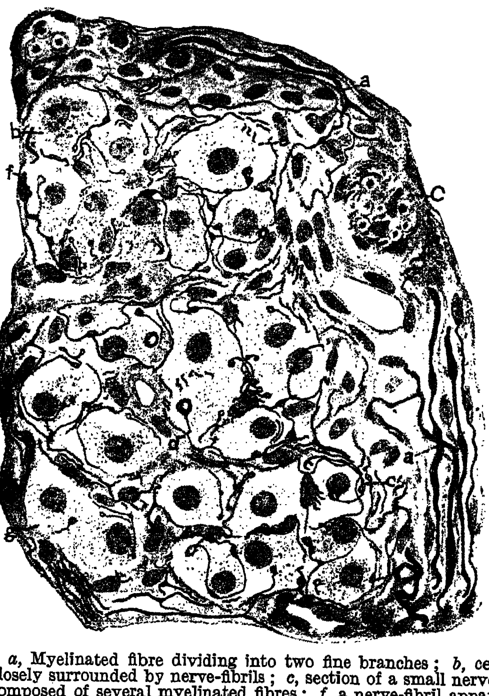
Vessels and Nerves.—The *arteries* supplying the suprarenal glands are numerous and of comparatively large size; they are derived from the aorta, and the phrenic and renal arteries. In the cortical part of the gland they break up into capillaries which end in the sinusoids of the medullary portion; the latter open into the veins near the centre of the medulla.

The *suprarenal vein* emerges from the hilum of the gland; that of the right gland opens into the inferior vena cava, that of the left into the left renal vein.

The *lymph* vessels end in the lateral aortic glands.

The *nerves* are exceedingly numerous, and are derived from the splanchnic nerves through the cœliac and renal plexuses, and, according to Bergmann, from the phrenic and vagus nerves. They enter the lower and medial part of the capsule, traverse the cortex, and end around the cells of the medulla. They have numerous small ganglia developed upon them in the medullary portion of the gland.

FIG. 1261.—A section of the carotid body, showing nerve-fibres distributed to the cells. (de Castro.) (From Sharpey-Schafer's *Essentials of Histology*.)



a, Myelinated fibre dividing into two fine branches; *b*, cell closely surrounded by nerve-fibrils; *c*, section of a small nerve, composed of several myelinated fibres; *f*, a nerve-fibril apparently ending within the cytoplasm of a cell; *g*, a nerve-fibril ending between the cells.

The Carotid Bodies

The carotid bodies, two in number, are situated one on each side of the neck, behind the common carotid artery at its point of bifurcation into the external and internal carotid

trunks. They are reddish-brown in colour, and oval in shape, the long diameter measuring about 5 mm.

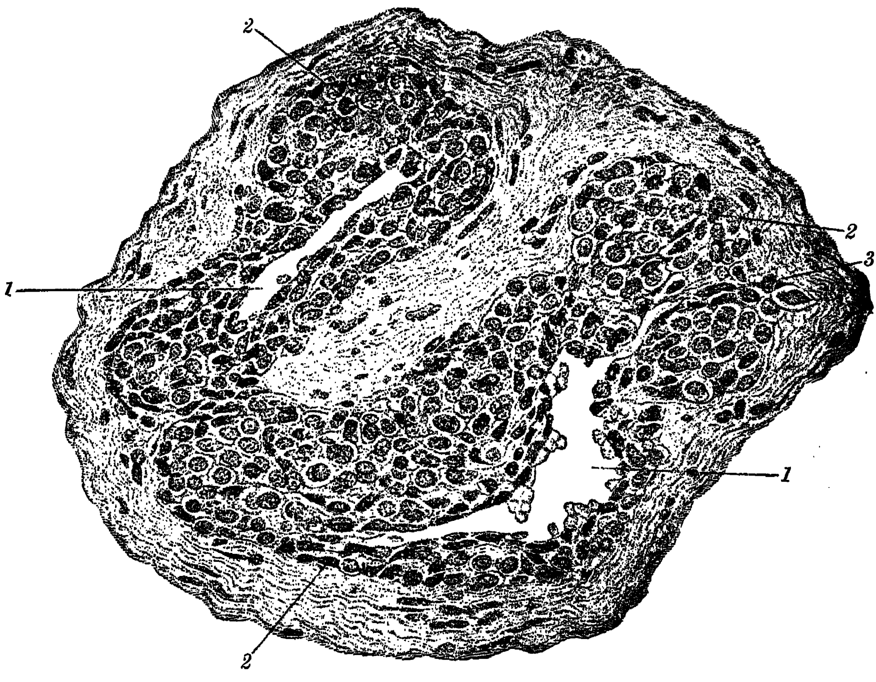
Structure.—Each is invested by a fibrous capsule and consists largely of spherical or irregular masses of chromaffin cells (fig. 1261)—the masses being more or less isolated from one another by septa which extend inwards from the deep surface of the capsule. The cells are polyhedral in shape, and each contains a large nucleus imbedded in finely granular protoplasm. Numerous nerve-fibres, derived from the superior cervical ganglion of the sympathetic trunk, and from the glossopharyngeal nerve, are distributed throughout the organ, and a network of large, sinusoidal capillaries ramifies amongst the cells. De Castro believes that the nervous constituents have a higher functional value than the chromaffin cells, and he regards the gland, not as an endocrine organ, but as a sensory organ associated with the vascular system and, possibly, concerned with the regulation of blood-pressure. It is not improbable that some functional significance may be attached to the intimate topographical relationship of the carotid body to the carotid sinus (p. 700).

The carotid bodies are derived from the masses of sympathochromaffin cells which give origin to the superior cervical ganglia of the sympathetic trunks.

The Coccygeal Body

The coccygeal body is placed in front of, or immediately below, the tip of the coccyx. It is about 2·5 mm. in diameter and is irregularly oval in shape; several smaller nodules are found around or near the main mass.

Fig. 1262.—A section through the coccygeal body. (Walker.) (From Sharpey-Schafer's *Essentials of Histology.*)



1, Blood-sinusoids; 2, gland-cells; 3, connective tissue stroma.

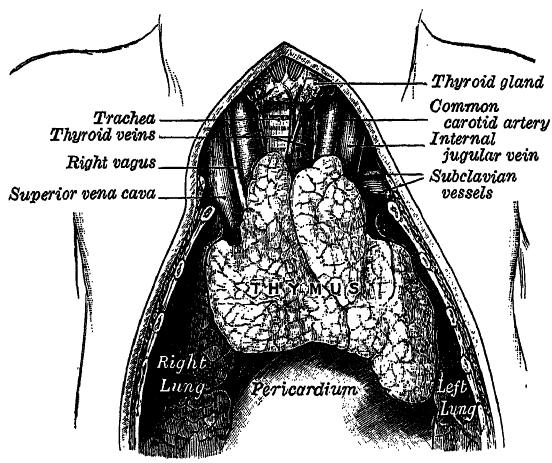
Structure.—The coccygeal body consists of irregular masses of round or polyhedral cells (fig. 1262), the cells of each mass being grouped around a dilated, sinusoidal capillary vessel. Each cell contains a large, round or oval nucleus, the protoplasm surrounding which is clear and is not stained by chromic salts.* The coccygeal body probably has a sympathochromaffin origin but, owing to the fact that it cannot be identified before the fourth month, the details of its development are uncertain.

* Consult the following article: "Über die menschliche Steissdrüse," von J. W. Thomson Walker, *Archiv für mikroskopische Anatomie und Entwickelungsgeschichte*, Band 64, 1904.

The Thymus (fig. 1263)

The **thymus** increases in size until the age of puberty, after which it dwindles and undergoes a gradual involution. Hammer maintains that it may persist and function even in advanced life. If examined when its growth is most active, it will be found to consist of two lobes placed in close contact along the median plane, situated partly in the thorax, partly in the neck, and extending from the fourth costal cartilage upwards, as high as the lower border of the thyroid gland. It is covered by the sternum, and by the origins of the Sternohyoid and Sternothyroid muscles. Below, it rests upon the pericardium, being separated from the aortic arch and great vessels by a layer of fascia. In the neck it lies on the front and sides of the trachea, behind the Sternohyoid and Sternothyroid muscles. The two lobes generally differ in size; they are occasionally united by connective tissue, so as to form a single mass; sometimes they are separated by an intermediate lobe. The thymus is of a pinkish-grey colour,

Fig. 1263.—The thymus of a full-time fœtus. Exposed *in situ.*



soft, and lobulated on its surfaces. At birth it weighs about 13 gm., and at puberty between 35 and 40 gm.; it is heavier in the male than in the female. Small nodules of thymic tissue may be found in the neighbourhood of the thyroid gland, and are frequently closely associated with the parathyroid glands.

Structure.—Each lateral lobe is composed of numerous lobules held together by delicate areolar tissue, the entire gland being enclosed in an investing capsule of a similar but denser structure. The primary lobules vary in size and are made up of a number of small nodules or follicles, which are irregular in shape and are more or less fused together, especially towards the interior of the gland. Each follicle (fig. 1264A) is from 1 mm. to 2 mm. in diameter and consists of a cortical and a medullary portion; it is enclosed in a connective tissue capsule, from which septa pass into its substance, but do not extend as far as the medullary portion of the follicle. The *cortical portion* is mainly composed of lymphocytes, supported by a network of finely branched cells, which is continuous with a similar network in the medullary portion. This network forms an adventitia to the blood-vessels. In the *medullary portion* the lymphoid cells are fewer, and the reticulum is coarser than in the cortex; it contains nest-like bodies, termed the *concentric corpuscles* of Hassall. These corpuscles are composed of a central mass, consisting of one or more granular cells, and of a capsule which is formed of concentrically arranged epithelioid cells (fig. 1264B). Eosinophil and polymorphonuclear leucocytes are also found in the gland.

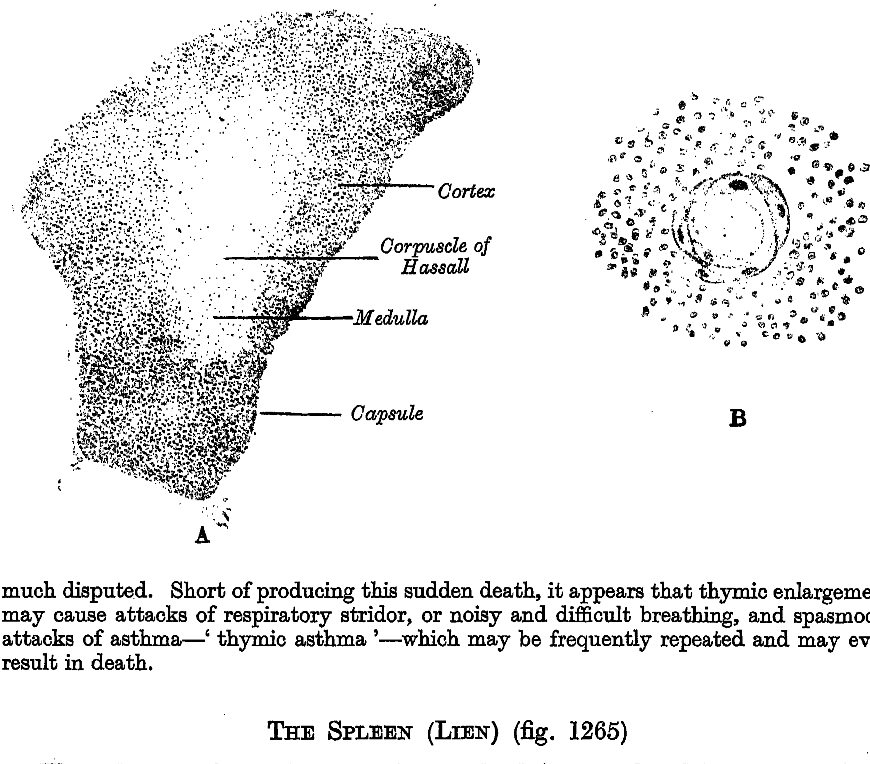
Each follicle is surrounded by a vascular plexus, from which vessels pass into the interior, and radiate from the periphery towards the centre, forming a second zone just within the margin of the medullary portion. In the centre of the medullary portion there are very few vessels, and they are of minute size.

The cortical part begins to atrophy before the medullary part, and its decrease in size is mainly owing to a diminution in the number of lymphocytes.

Vessels and Nerves.—The blood-supply of the thymus is scanty. The *arteries* are derived from the internal mammary, and the superior and inferior thyroids. The *veins* end in the left innominate vein, and in the thyroid veins. The *lymph vessels* are described on p. 879. The *nerves* are exceedingly minute; they are derived from the vagi and sympathetic. Branches from the descendens hypoglossi and phrenic reach the investing capsule but do not penetrate the substance of the gland.

Applied Anatomy.—Sudden death—'thymus death'—with heart-failure, and with or without acute respiratory embarrassment, has been recorded in a number of infants and children in whom the thymus was considerably enlarged, and the lymphatic tissues throughout the body showed general hypertrophy, but who showed no other evidence of disease. Such deaths have often occurred during the administration of anæsthetics, particularly chloroform. How far the enlarged thymus was responsible for the death of these patients, and, if it was responsible, how far its action was mechanical, are points that have been

FIG. 1264.—A, A section through a follicle of the thymus of a kitten. ×60 B, a corpuscle of Hassall. ×350. Stained with picrocarmine.



much disputed. Short of producing this sudden death, it appears that thymic enlargement may cause attacks of respiratory stridor, or noisy and difficult breathing, and spasmodic attacks of asthma—'thymic asthma'—which may be frequently repeated and may even result in death.

THE SPLEEN (LIEN) (fig. 1265)

The spleen is situated principally in the left hypochondriac region of the abdomen, but its upper end extends into the epigastric region; it lies between the fundus of the stomach and the Diaphragm. It is the largest of the ductless glands, and is of an oblong, flattened form, soft, of very friable consistence, highly vascular, and of a dark purplish colour.

Relations.—The *diaphragmatic surface* is convex, smooth and faces upwards, backwards, and to the left, except at its upper end, where it faces slightly medially. It is in relation with the under surface of the Diaphragm, which separates it from the ninth, tenth, and eleventh ribs of the left side, and the intervening lower borders of the left lung and pleura.

The *visceral surface* (fig. 1265) is directed towards the abdominal cavity, and presents gastric, renal, pancreatic and colic impressions.

The *gastric impression*, directed forwards, upwards, and medially, is broad and concave. It is in contact with the posterior wall of the stomach, from which it is separated by a recess of the greater sac. It presents near its lower limit a long fissure, termed the *hilum*. This is pierced by several irregular apertures for the entrance and exit of vessels and nerves.

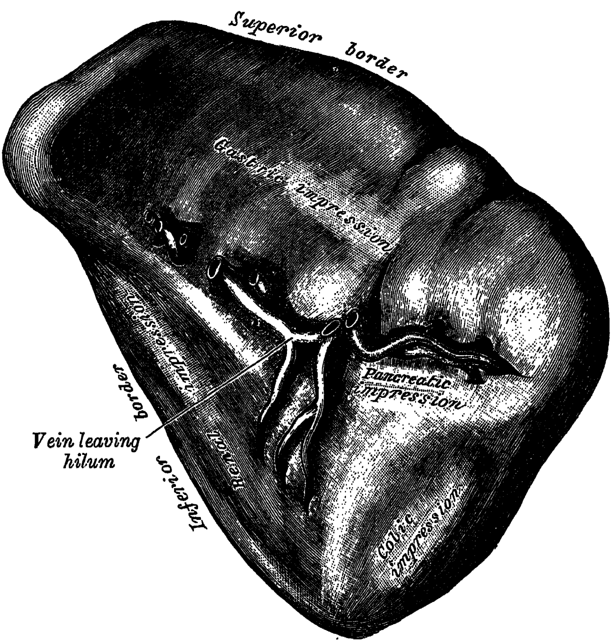
The *renal impression*, which is very gently concave, is placed on the lower part of the visceral surface and is separated from the gastric impression above by a raised margin. It is directed medially, downwards and a little backwards, and is related to the upper and lateral part of the anterior surface of the left kidney and, sometimes, to the upper pole of the left suprarenal gland.

The *colic impression* is placed at the lateral extremity of the spleen and is usually flattened. It is related to the left colic flexure.

The *pancreatic impression*, when present, is small and is placed between the colic impression and the lateral part of the hilum. It is directly related to the tail of the pancreas.

The *superior border* separates the diaphragmatic surface from the gastric impression. It is usually convex upwards and is marked, near its lateral end,

FIG. 1265.—The visceral surface of the spleen.



by one or two notches of variable depth. The *inferior border* separates the renal impression from the diaphragmatic surface and lies between the Diaphragm and the upper part of the lateral border of the left kidney. It is blunter and more rounded than the superior border and corresponds to the lower margin of the eleventh rib.

The *medial end* of the spleen is blunt and rounded in most cases. It is directed towards the vertebral column and lies on a level with the twelfth thoracic vertebra. The *lateral end* is more expanded, and commonly takes the form of a margin connecting the lateral ends of the upper and lower borders. It is related to the left colic flexure and to the phrenicocolic ligament.

The spleen is almost entirely surrounded by peritoneum, which is firmly adherent to its capsule. Recesses of the greater sac intervene between the spleen and the stomach, and between the spleen and the left kidney. It develops in the upper part of the dorsal mesogastrium (p. 179) and remains connected to the stomach and to the posterior abdominal wall by two folds of peritoneum. One, termed the *lienorenal ligament*, is derived from the peritoneum where the wall of the general peritoneal cavity comes into contact with the lesser sac between the left kidney and spleen ; the splenic vessels pass between its two layers (fig. 1162). The other fold, termed the *gastrosplenic ligament*, also consists of two layers, and is formed by the meeting of the walls of the greater and lesser sacs between the spleen and stomach (fig. 1162) ; the short gastric and left

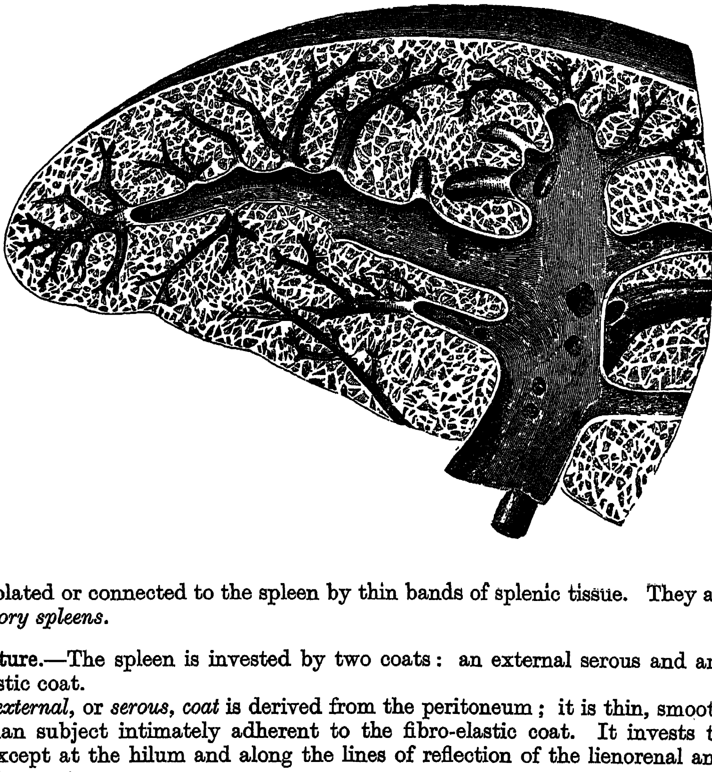
gastro-epiploic branches of the splenic artery run between its two layers. The lateral part of the lateral end of the spleen is in contact with the phrenico-colic ligament (p. 1314).

The size and weight of the spleen vary at different periods of life, in different individuals, and in the same individual under different conditions. *In the adult* it is usually about 12 cm. in length, 7 cm. in breadth, and 3 or 4 cm. in thickness, and weighs about 200 gm., but it tends to diminish in size and weight with advancing age.

The size of the spleen slowly increases during digestion, and varies according to the state of nutrition of the body, being large in highly fed, and small in starved, animals. In malarial fever it is greatly enlarged, and may weigh as much as 9 kilos.

Frequently in the neighbourhood of the spleen, and especially in the gastrosplenic ligament and greater omentum, small encapsulated nodules of splenic tissue may be found,

FIG. 1266.—A transverse section through the spleen, showing the trabecular tissue and the splenic vein and its tributaries.



either isolated or connected to the spleen by thin bands of splenic tissue. They are known as *accessory spleens.*

Structure.—The spleen is invested by two coats: an external serous and an internal fibro-elastic coat.

The *external,* or *serous, coat* is derived from the peritoneum; it is thin, smooth, and in the human subject intimately adherent to the fibro-elastic coat. It invests the entire organ, except at the hilum and along the lines of reflection of the lienorenal and gastrosplenic ligaments.

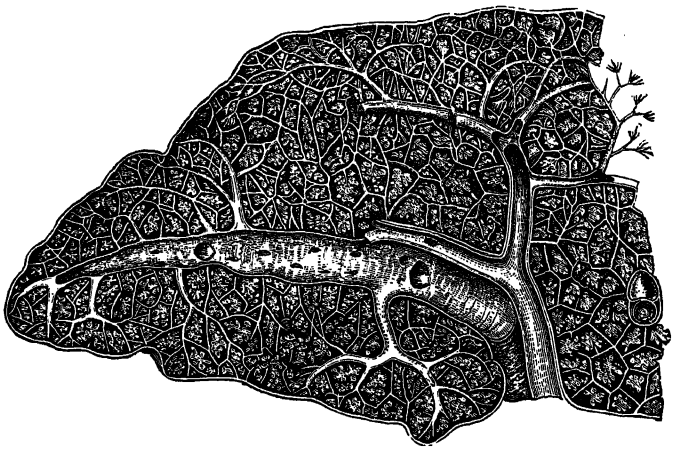
The *fibro-elastic coat,* or *tunica albuginea,* invests the organ, and at the hilum is reflected inwards upon the vessels in the form of sheaths. From these sheaths, as well as from the inner surface of the fibro-elastic coat, numerous small fibrous bands, termed *trabeculæ* (fig. 1266), are given off in all directions; these unite to form the framework of the spleen, in the interspaces of which the *splenic pulp* is contained.

The fibro-elastic coat, the sheaths of the vessels, and the trabeculæ, are composed of white, and yellow elastic, fibres, the latter predominating. It is owing to the presence of the elastic tissue that the spleen possesses a considerable amount of elasticity, which allows of the very great variations in size that it presents under certain circumstances. In addition to these constituents there is a small amount of non-striped muscular fibre. In some mammals (e.g. dog, pig, and cat) the trabeculæ consist chiefly of muscular tissue.

The *splenic pulp* is a soft mass of a dark reddish-brown colour; it consists of a fine reticulum of fibres, continuous with those of the trabeculæ, to which flat, branching cells are applied. The meshes of the reticulum are filled with blood, in which, however, the white corpuscles are found to be in larger proportion than they are in ordinary blood. Large, rounded cells, termed *splenic cells,* are also seen; these are capable of amœboid movement, and often contain pigment and red blood-corpuscles in their interior. The

cells of the reticulum possess round or oval nuclei, and like the splenic cells they may contain pigment-granules in their cytoplasm; they do not stain deeply with carmine, and in this respect differ from the cells of the lymphatic nodules. In the young spleen

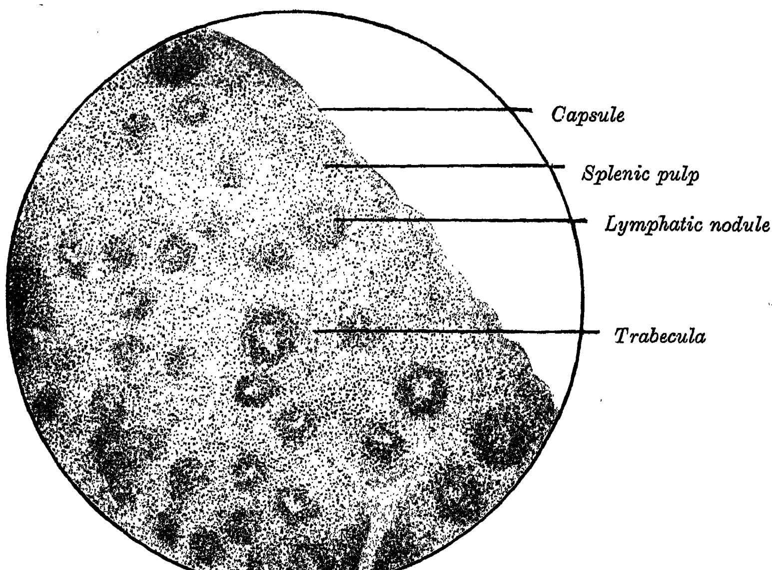
FIG. 1267.—A transverse section through the human spleen, showing the distribution of the splenic artery and its branches.



giant cells may be found, each containing numerous nuclei or one compound nucleus. Nucleated red blood-corpuscles have also been found in the spleen in young animals.

Blood-vessels of the spleen.—The splenic artery (p. 765) is remarkable for its large calibre in proportion to the size of the organ, and also for its tortuous course. It divides into six or more branches, which enter the hilum of the spleen and ramify throughout its substance

FIG. 1268.—A section through a portion of the human spleen. Stained with hæmatoxylin and eosin. × 15.



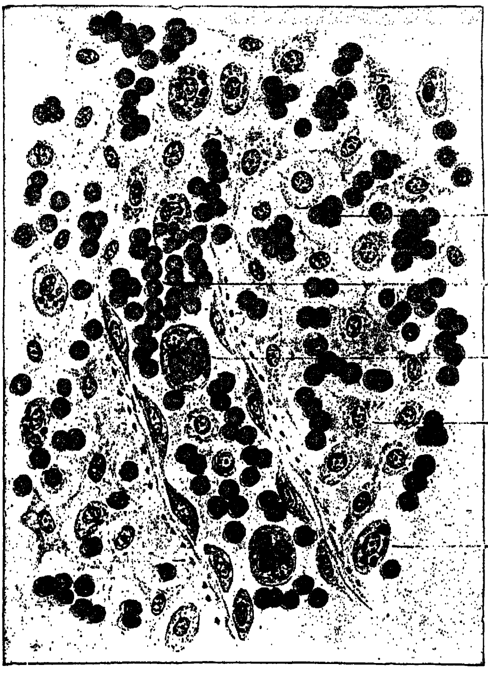
(fig. 1267), receiving sheaths from an involution of the external fibrous tissue. Similar sheaths also invest the nerves and veins.

Each branch runs in the transverse axis of the organ, from within outwards, diminishing in size during its transit, and giving off in its passage smaller branches, some of which pass to the anterior, others to the posterior, part. These ultimately leave the trabecular sheaths, and terminate in the proper substance of the spleen in small tufts or pencils of

minute arterioles, which open into the interstices of the reticulum formed by the branched sustentacular cells. The branches of the splenic artery are 'end arteries' (p. 690).

The *arterioles* differ in structure from the larger arterial vessels in that their outer coat consists of lymphoid tissue. This coat exhibits localized spheroidal thickenings, termed the *lymphatic nodules* (*Malpighian bodies*) of the spleen (fig. 1268). These bodies vary in size from about 0·25 mm. to 1 mm. in diameter. In transverse sections the artery, in the majority of cases, is found in an eccentric position. The lymphatic nodules are visible to the naked eye on the surface of a fresh section of the organ, appearing as minute semi-opaque dots of a whitish colour in the dark substance of the pulp. The reticulum of the lymphoid tissue is made up of extremely fine fibrils, and is comparatively open in the centre of the body, but closer at its periphery.

FIG. 1269.—Thin section of spleen-pulp of child, highly magnified, showing the mode of origin of a small vein in the interstices of the pulp. (E. Sharpey-Schafer.) ×400. (From Sharpey-Schafer's *Essentials of Histology*.)



a, Blood in pulp ; *a′*, blood in vein ; *b*, phagocyte in vein ; *c*, branched cell of pulp ; *d*, phagocytic splenic cell.

The arterioles end by opening freely into the splenic pulp ; their walls become much attenuated, they lose their tubular character, and the endothelial cells ramify, their processes being directly connected with those of the reticular cells of the pulp. The blood thus finds its way into the interstices of the reticulated tissue of the splenic pulp. It is then collected by the rootlets of the veins, which begin much in the same way as the arteries end (fig. 1269). The connective tissue corpuscles of the pulp arrange themselves in rows, in such a way as to form an elongated space or sinus. They become elongated and spindle-shaped, and overlap each other at their extremities, and thus form a sort of endothelial lining of the path or sinus, which is the radicle of a vein. On the outer surface of these sinuses delicate transverse lines or markings, which are due to minute elastic fibrils arranged in a circular manner, are seen. Thus the channel obtains an external investment, and gradually becomes converted into a small vein, which after a short course acquires a coat of ordinary connective tissue, lined with a layer of endothelial cells continuous with the supporting cells of the pulp. The smaller veins unite to form larger ones : these do not accompany the arteries, but soon enter the trabecular sheaths of the capsule, and by their junction form six or more vessels. These emerge from the hilum and, uniting, constitute the splenic vein (p. 842), which is the largest radicle of the portal vein.

The veins are remarkable for their numerous anastomoses.

The lymph vessels are described on p. 868.

The *nerves* are derived from the cœliac plexus and are chiefly non-medullated. They are distributed to the blood-vessels and to the smooth muscle of the capsule and trabeculæ.

Applied Anatomy.—Injury of the spleen is less common than that of the liver, on account of its protected situation and connexions. It may be ruptured by direct or indirect violence; torn by a broken rib; or injured by a punctured or gunshot wound. When the organ is enlarged the chance of rupture is increased. The great risk is hæmorrhage, owing to the vascularity of the organ and the absence of a proper system of capillaries. The injury, however, is not necessarily fatal, and this would appear to be due, in a great measure, to the contractile power of the capsule, which narrows the wound and prevents the escape of blood. In cases where the diagnosis is clear, and the symptoms indicate danger to life, laparotomy must be performed, and the spleen removed. When removing the spleen it must be remembered that the tail of the pancreas is in contact with it, and should be avoided when the vessels are ligatured.

SURFACE ANATOMY

SURFACE anatomy deals with the relationships of structures to the surface of the body, and, in order that these relationships may be determined, use is made of surface landmarks which can be identified easily. Many subcutaneous as well as many deeper structures produce irregularities in the surface contour of the body which can be appreciated on inspection ; others, while yielding no visible sign of their presence, can be felt through the skin, and are therefore capable of identification by means of palpation. Most of the deeper structures can neither be seen nor felt through the skin, but a knowledge of their topographical relations in the body makes their reference to visible or palpable landmarks a matter of relatively little difficulty.

Bones, cartilages, muscles and tendons provide most of the visible and palpable landmarks. When bony or cartilaginous landmarks are being sought, their recognition is facilitated by the relaxation of the muscles in their neighbourhood. On the other hand, muscles and tendons can be identified most easily when they are thrown into contraction and, preferably, when they are working under load. In cases where arteries are placed superficially and lie on bone, their position can be indicated accurately as their pulsations render their identification easy. Nerves, similarly placed, can be rolled under the skin against the bone and can be identified in that way. A few other structures, e.g. the parotid duct, the spermatic cord, etc., can also be felt through the skin.

In the succeeding pages the subject-matter is treated regionally, and in each case a description of the visible and palpable landmarks precedes the description of the surface relations of the other structures in the region. It would be possible to enumerate the surface relations of all the structures in the human body, but, while all the important visible and palpable landmarks will be included, the surface relations of other structures will be described only in those cases where the information is likely to be of practical value and may be utilised in connexion with the examination or treatment of patients.

THE SURFACE ANATOMY OF THE UPPER LIMB

The Shoulder and Axillary Regions

Surface landmarks.—The *clavicle* forms a landmark which is both visible and palpable. Its outline can be traced from its expanded sternal end, which is the lateral boundary of the suprasternal notch, to its flattened acromial extremity. The line of the *acromioclavicular joint* is anteroposterior, but it is not easy to identify except in those cases where the upper border of the lateral end of the clavicle presents a well-marked ridge. The small depression which lies below the clavicle at the junction of its two curves constitutes the *infraclavicular fossa* (deltoideopectoral triangle) (fig. 1283) and intervenes between the surface elevations produced by the clavicular origins of the deltoid and the pectoralis major muscles.

The rounded lower, or lateral, border of the *pectoralis major* forms the anterior axillary fold and is rendered more conspicuous when the abducted arm is adducted against resistance ; it extends from the lower end of the lateral lip of the bicipital groove (intertubercular sulcus) of the humerus downwards and medially to the chest wall. When the arm is flexed to a right angle and maintained in that position against gravity, the *clavicular head* of the muscle is thrown into contraction, while the sternocostal head is relaxed. The lower border of the clavicular head can then be traced from the sternal end of the clavicle to the lower border of the anterior axillary fold, and it corresponds to the line of separation of the two heads of the muscle. When the flexed arm is extended against resistance, the clavicular head becomes relaxed, but the *sternocostal head* stands out in bold relief.

The *acromion* can be traced forwards along its medial margin from the acromioclavicular joint to its tip, and then backwards along its lateral margin across the top of the shoulder until it meets the crest of the scapular spine at the prominent *acromial angle*. From this angle the *crest of the scapular spine* (fig. 1286) runs downwards and medially to reach the medial border of the bone opposite the spine of the third thoracic vertebra. It is subcutaneous and is both visible and palpable. The *medial border* of the scapula is hidden in its upper part by the trapezius muscle, but, below the spine, it can be traced downwards and slightly laterally to the *inferior angle* (fig. 1286), which usually overlies the seventh intercostal space at the level of the spine of the seventh thoracic vertebra. When the arm is raised above the head, the position of the medial border is indicated by an oblique furrow. Although it is covered by the teres major and latissimus dorsi muscles, the inferior angle can easily be felt when it is approached from below, and it can be seen moving laterally and forwards round the chest wall when the arm is raised above the head.

The rounded contour of the normal shoulder is caused by the bulky *deltoid muscle* (fig. 1286), the limits of which can be determined accurately when the arm is maintained in the abducted position against gravity. The tendon of insertion can be identified about half-way down the lateral aspect of the humerus, and from its anterior aspect the anterior border of the muscle can be traced upwards and medially, across the tendon of the pectoralis major, to form the lateral boundary of the infraclavicular fossa. The posterior border of the muscle runs upwards and medially from the posterior aspect of the tendon of insertion and crosses the back of the shoulder to reach the crest of the scapular spine near its medial end. As it passes from its origin to its insertion the deltoid muscle is spread out over the lateral aspect of the greater tuberosity of the humerus, and it is actually this bony relationship which accounts for the normal rounded contour of the shoulder. When the greater tuberosity is displaced medially—a condition which is present in dislocation of the shoulder joint—the deltoid descends vertically to its insertion and the normal, rounded contour is lost.

The apex of the *coracoid process* can be made out indistinctly under cover of the anterior fibres of the deltoid. It lies 2·5 cm. vertically below the clavicle at the junction of the lateral fourth with the rest of the bone.

The posterior fold of the axilla, which reaches a lower level on the humerus than the anterior fold, is produced by the *latissimus dorsi* and the underlying *teres major* muscle. Both take part in adduction of the arm and, when attempts are made to adduct the abducted arm against resistance, the posterior fold of the axilla is accentuated and the lower, or lateral, border of the latissimus dorsi can be traced downwards to its attachment to the iliac crest.

When the arm is raised above the head, the lower five or six serrations of the *serratus anterior* muscle (fig. 1270) can be seen on the lateral aspect of the chest; they point downwards and forwards and interdigitate with the serrations of the external oblique muscle along a zigzag line.

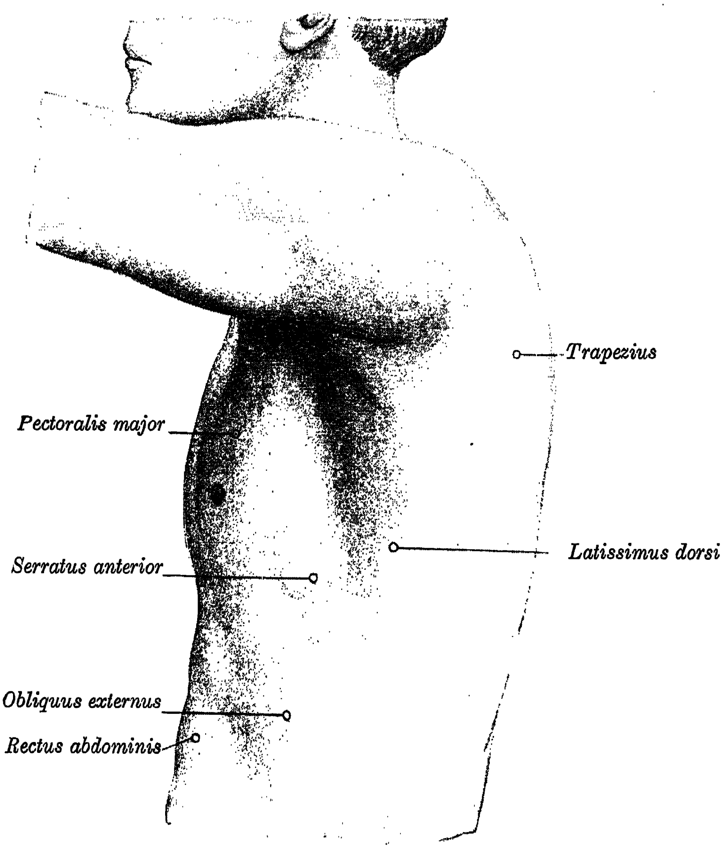
The *greater tuberosity* of the humerus constitutes the most lateral bony point in the shoulder region (fig. 1287, and Pl. III) and projects laterally below and in front of the acromial angle. It can be felt indistinctly on deep pressure through the deltoid muscle. The *lesser tuberosity* lies on the anterior aspect of the shoulder, 3 cm. below the tip of the acromion. If deep pressure is made through the deltoid at this point, the resistance due to the lesser tuberosity can be felt, and the bony prominence slips away from the examining finger when the humerus is rotated laterally, or medially.

The pulsation of the lower part of the *axillary artery* can be felt on palpation of the medial side of the arm, just in front of the posterior axillary fold, and in this situation the great nerves derived from the brachial plexus can be felt as tense cords when the arm is abducted. On deep pressure the *median nerve* can be rolled against the humerus, and tingling sensations are induced thereby in the central part of the palm of the hand.

The skin covering the shoulder is smooth and freely movable on the underlying structures. In the axilla there are numerous hairs and many sudoriferous and sebaceous glands.

Surface relations of other structures.—The *axillary artery* can be mapped out most conveniently when the arm is raised to a right angle with the trunk. It can be represented by a broad line drawn laterally from the middle of the clavicle to the point at which the pulsation of the vessel is felt. The *axillary vein* is closely applied to the medial side of the artery. In the upper part of its course the *cephalic vein* can be indicated by a line drawn upwards along the anterior border of the deltoid muscle, across the infraclavicular fossa, to end under cover of the clavicular head of the pectoralis major.

FIG. 1270.—The left side of the thorax.



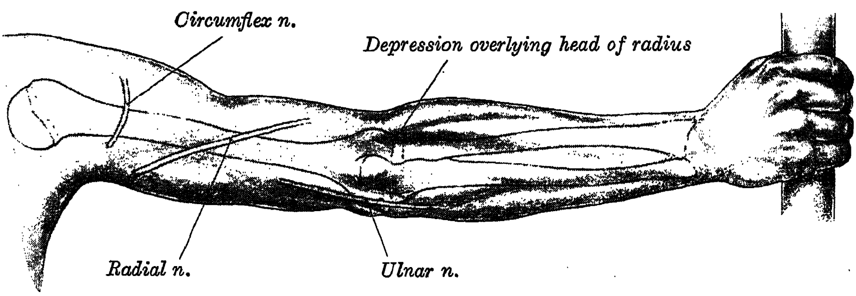
When the arm is by the side the anterior edge of the glenoid cavity can be marked out on the front of the shoulder by a line, 3 cm. long, drawn downwards from a point just lateral to the tip of the coracoid process. This line, which should be very slightly concave laterally, lies over the lower half of the shoulder joint.

The *mammary gland* covers a somewhat circular area, but its periphery is irregular and can be represented best by a wavy line. This line commences at the margin of the sternum opposite the sternal angle and runs downwards to the sternal end of the sixth costal cartilage. It is continued laterally, with a gentle convexity downwards, to the midaxillary line and then upwards into the axilla, where the tail of the gland reaches as far as the axillary vessels under cover of the pectoralis major muscle. Finally, the line curves medially along the second rib and cartilage to the sternum. In the male, the *nipple* lies over the fourth intercostal space (fig. 1291), rather more than 10 cm. from the median plane ; in the female, especially when the breast is pendulous, it is found at a lower level.

The Arm and Elbow Region

Surface landmarks.—When the arm is grasped firmly, the *shaft of the humerus* can be made out, but the strong muscles that clothe it obscure its outline and render it indistinct. At the lower end of the bone the *medial epicondyle* (fig. 1271) forms a conspicuous landmark and can be examined readily, especially when the elbow is flexed passively. The *ulnar nerve* lies posterior to the base of the epicondyle and can be rolled from side to side against the bone. The *lateral epicondyle*, which lies on a more anterior plane when the arm is by the side (p. 346), is not so prominent, but its posterior surface can be felt, and its lateral margin can be traced up into the *lateral supracondylar ridge*, when deep pressure is exerted. If the extended elbow is viewed from behind, a well-marked depression can be seen to the lateral side of the middle line. It is bounded laterally by the fleshy elevation formed by the superficial group of the extensor muscles of the forearm, and medially by the lateral side of the olecranon. The floor of the depression contains, in its upper part, the posterior surface of the *lateral epicondyle* and, in its lower part, the *head of the radius.*

Fig. 1271.—The back of the right upper limb, showing the surface markings for the bones and nerves.



Although covered with the annular ligament and the anconeus muscle, the head of the radius can be felt to rotate when the forearm is alternately pronated and supinated. Between the lateral epicondyle and the head of the radius a transverse depression can be felt; it corresponds to the *humeroradial part of the elbow joint.*

When the elbow is extended, the apex of the *olecranon* can be felt on, or just above, the line joining the two epicondyles, nearer to the medial than to the lateral side (fig. 1271). When the elbow is flexed, the apex of the olecranon descends, and the three bony points form the angles of an isosceles triangle. In this position of the limb the proximal surface of the olecranon can be explored, but it is covered with the tendon of insertion of the triceps and can only be made out indistinctly. The posterior surface of the olecranon is subcutaneous and tapers from above downwards; it can be felt without difficulty immediately below the apex.

On the front of the arm, the *biceps* (fig. 1273) is a conspicuous elevation, diminishing above, where it is covered with the pectoralis major tendon, and again below where it gives place to its tendon just above the elbow. Shallow furrows indicate its medial and lateral borders. When the elbow is flexed against resistance the muscle is thrown into contraction, and its tendon of insertion can be grasped between the finger and thumb and followed down into the cubital fossa. From the medial border of the tendon the sharp, upper margin of the *bicipital aponeurosis* can be traced downwards and medially to the elevation caused by the superficial group of the flexor muscles of the forearm. The aponeurosis is crossed, almost at right angles, by the *median cubital vein*,

which can usually be seen through the skin running upwards and medially from the cephalic vein to join the basilic vein.

The *coracobrachialis muscle* forms an inconspicuous rounded ridge on the upper part of the medial side of the arm and in the lower part of the lateral wall of the axilla (fig. 1273). It overlaps the upper part of the brachial artery and can be identified by its close relationship to the vessel.

On the posterior aspect of the arm, the *lateral head of the triceps* forms an elevation, medial and parallel to the posterior border of the deltoid muscle; it stands out prominently, when the elbow is extended actively. The fleshy mass which lies to its medial side, and disappears above under cover of the deltoid muscle, is produced by the *long head of the triceps*.

The pulsation of the *brachial artery* can be felt in the furrow along the medial side of the biceps and, at its upper part, in the depression behind the coracobrachialis muscle. In its lower part, it lies close to the medial side of the biceps tendon, but on a more posterior plane, and it disappears behind the bicipital aponeurosis. It can be marked out by a line drawn from the termination of the axillary artery downwards and slightly laterally to a point at the level of the neck of the radius in the middle line of the limb. It should be noted that, although at its upper end the brachial artery lies medial to the humerus, it lies directly in front of the lower end of the shaft of the bone.

Surface relations of other structures.—The *musculocutaneous nerve* can be represented in the arm by a line drawn from the lateral side of the axillary artery 3 cm. above its termination; it passes downwards and laterally across the elevations produced by the coracobrachialis and the biceps to the lateral side of the biceps tendon of insertion. The *median nerve* is intimately related to the brachial artery throughout its course in the arm. Placed at first on the lateral side, the nerve crosses in front of the vessel about half-way down the arm and thereafter descends close to its medial side into the cubital fossa (fig. 1274). The *ulnar nerve* can be represented by a line which follows the medial side of the upper part of the brachial artery, but diverges from it half-way down the arm and runs downwards and medially to the base of the medial epicondyle. The *radial nerve* (fig. 1271) in the arm corresponds to a line drawn from the commencement of the brachial artery and carried downwards and laterally across the elevations produced by the long and lateral heads of the triceps to the junction of the upper and middle thirds of a line joining the lateral epicondyle to the insertion of the deltoid muscle. (This line represents the edge of the *lateral intermuscular septum* of the arm.) The line of the nerve is then continued downwards on the front of the arm to the level of the lateral epicondyle, where it lies 1 cm. or less to the lateral side of the tendon of the biceps. The *circumflex nerve* crosses the humerus about 2 cm. above the mid-point of a line joining the tip of the acromion to the insertion of the deltoid muscle (fig. 1287).

The level of the *elbow-joint* is situated 2 cm. below the line joining the two epicondyles (Pl. V, fig 1). It is not horizontal but slopes downwards and medially from its lateral end and this obliquity produces the 'carrying angle' (p. 467). On the posterior surface of the limb, the level of the joint can be determined more easily, as the humeroradial articulation can be felt through the skin (p. 1430).

The Forearm and Wrist

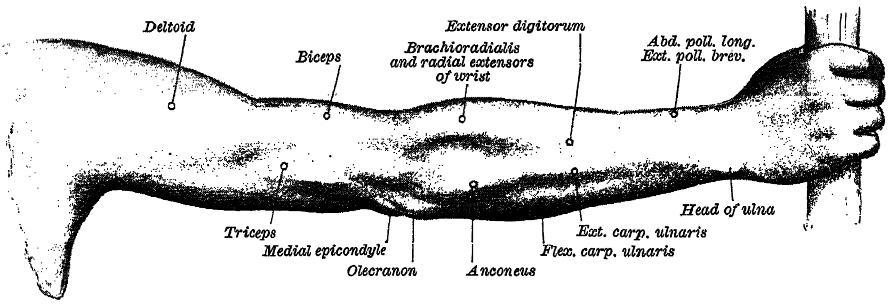
Surface landmarks.—The depression in the middle of the upper part of the front of the forearm corresponds to the *cubital fossa* (fig. 1273). The fleshy elevation which forms its medial border is formed by the *pronator teres* and the *superficial group of the flexor muscles of the forearm*; it does not extend upwards much above the level of the medial epicondyle. The elevation which forms the lateral border of the cubital fossa is formed by the *brachioradialis* and the *superficial group of the extensor muscles* of the forearm; it extends upwards to a much higher level than the medial border of the fossa. The *brachioradialis* is the most superficial of the muscles on the lateral side; it is thrown into contraction when the forearm—preferably in the semiprone position—is flexed

against resistance, and it then stands out as a prominent ridge, extending upwards beyond the level of the elbow-joint on the lateral side of the arm.

The line separating the flexors from the extensors on the back of the forearm is indicated by a longitudinal furrow, which is seen best when the elbow is fully flexed. This furrow corresponds to the *posterior border of the ulna* (fig. 1272), which is subcutaneous throughout its whole extent, from the subcutaneous surface of the olecranon above to the *styloid process* of the ulna below. The large fleshy mass on the medial side of the furrow is produced by the *flexor digitorum profundus,* covered with the aponeurosis which binds the flexor carpi ulnaris to the posterior border of the ulna. The fleshy mass on the lateral side of the furrow is produced by the *extensor carpi ulnaris, extensor digiti minimi, extensor digitorum* and the *radial extensors of the wrist,* in that order from the medial to the lateral side. The limits of the extensor carpi ulnaris can be determined during adduction of the hand, and those of the extensor digiti minimi, during extension of the little finger.

In the lower part of the forearm the fleshy bellies of the muscles merge into their tendons and the breadth of the forearm becomes diminished correspondingly (fig. 1272). An oblique elevation is visible on the lateral part of the dorsal aspect at the junction of the lower fourth with the rest of the forearm. It

FIG. 1272.—The back of the right upper limb.



becomes more conspicuous when the thumb is extended, as it is produced by the *extensor pollicis brevis* and the *abductor pollicis longus,* which come to the surface in the interval between the extensor carpi radialis brevis and the extensor digitorum, where the fleshy bellies of these muscles merge into their tendons. Although the bodies of the radius and ulna—apart from the posterior border of the latter—can only be felt indistinctly, their lower ends form landmarks which are both visible and palpable. The expanded *lower end of the radius* forms a slight surface elevation on the lateral side of the wrist, about 1 cm. above the base of the thenar eminence. Its lateral aspect is obscured by the tendons of the abductor pollicis longus and the extensor pollicis brevis, but, unless the thumb is actively extended, it can be traced downwards into the *styloid process.* The salient ridge which marks the anterior limit of the lateral aspect of the lower end of the radius is easily felt ; it gives attachment to the lateral end of the extensor retinaculum (dorsal carpal ligament). To its medial side, the *radial pulse* indicates the position of the radial artery at this level. The anterior border of the lower end of the radius projects forwards, and, despite the overlying tendons, can be felt as a transverse ridge, which lies nearly 2 cm. above the base of the thenar eminence. The posterior aspect of the lower end of the radius is also partly obscured by tendons, but can be palpated without difficulty. It presents a more or less well-marked *tubercle,* which is grooved obliquely by the extensor pollicis longus tendon and separates the groove for the extensor carpi radialis brevis from the groove for the extensor digitorum and the extensor indicis. This tubercle lies in line with the cleft between the index and the middle fingers.

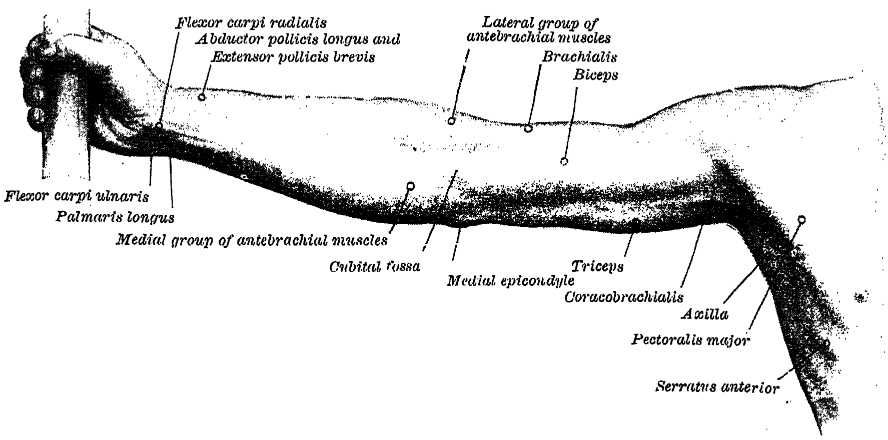
The rounded *head of the ulna* (fig. 1272) forms a surface elevation on the medial part of the posterior aspect of the wrist, when the hand is pronated ; and can be gripped between the finger and thumb, when the supinated hand

is flexed passively. The *styloid process of the ulna* projects downwards from the posteromedial aspect of the head of the bone. It lies at a higher level, and on a more posterior plane, than the *styloid process of the radius*. The relative positions of these two bony points can be determined satisfactorily, if the wrist is grasped firmly between the finger and thumb and pressure is exercised in an upward direction.

When the wrist is flexed against resistance, two tendons stand out prominently on its anterior aspect; the more lateral is the *flexor carpi radialis* and the more medial is the *palmaris longus* (fig. 1273), which lies approximately in the middle line of the limb. On the ulnar side the tendon of the *flexor carpi ulnaris* can be identified, and between it and the palmaris longus the flexor tendons for the little and ring fingers can be felt indistinctly.

When the thumb is extended, an intertendinous depression, known as the 'anatomical snuff-box,' is seen on the lateral aspect of the wrist just below the prominence caused by the lower end of the radius. It is bounded in front by the tendons of the *abductor pollicis longus* and the *extensor pollicis brevis*, which lie close to each other, and behind by the tendon of the *extensor pollicis longus*,

FIG. 1273.—The front of the right upper limb.



which stands out conspicuously. The tendons of the *radial extensors of the wrist* can be identified on the back of the carpus most easily when the fist is alternately clenched and relaxed; the extensor carpi radialis longus tendon is partly obscured by the extensor pollicis longus, but the tendon of the extensor carpi radialis brevis, which is situated more medially, can be felt without difficulty.

The *bones of the carpus* are, for the most part, obscured by the flexor tendons, the flexor retinaculum (transverse carpal ligament), and the muscles of the thenar and hypothenar eminences. Certain of them, however, can be palpated and identified. The *pisiform bone* forms an elevation which can be seen and felt on the palmar aspect of the wrist at the medial part of the base of the hypothenar eminence; it can be moved over the articular surface of the triquetral bone, when the wrist is kept passively flexed. The *hook of the hamate bone* can be identified, although it is not so prominent; it lies 2·5 cm. below the pisiform bone and is in line with the ulnar border of the ring finger. On deep pressure in this situation, the superficial division of the ulnar nerve can be rolled from side to side over the tip of the hook. The *tubercle of the scaphoid* bone is situated at the base of the thenar eminence and is crossed by the tendon of the flexor carpi radialis, by which it is partly hidden. In many subjects it forms a small elevation on the surface. Immediately beyond it, but covered with the muscles of the thenar eminence, the *crest of the trapezium* may be recognised, when deep pressure is exercised.

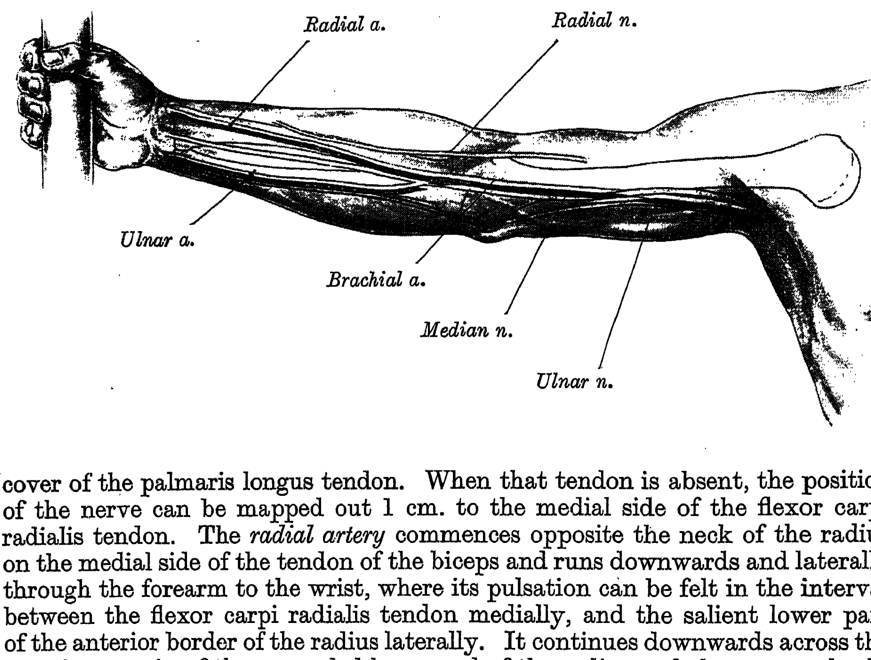
On the medial side and front of the forearm the skin is thin and smooth, and contains few hairs but many sweat glands; on the lateral side and

back of the forearm it is thicker, and contains more hairs but fewer sweat glands.

Surface relations of other structures.—The *ulnar nerve* in the forearm corresponds to a line drawn from the base of the medial epicondyle of the humerus to the lateral edge of the pisiform bone ; in the lower part of the forearm this line lies along the lateral side of the flexor carpi ulnaris tendon. The *ulnar artery* commences in the middle line of the limb, opposite the neck of the radius, and can be represented in the upper, and deepest, part of its course by a line which passes downwards and medially, across the elevation produced by the superficial flexor muscles of the forearm, to reach the lateral side of the ulnar nerve at the junction of the upper third with the lower two-thirds of the forearm. In the rest of its course in the forearm the ulnar artery lies along the lateral side of the ulnar nerve.

The *median nerve* enters the forearm on the medial side of the termination of the brachial artery (fig. 1274) and runs vertically downwards, approximately in the middle line of the limb. At the wrist it projects laterally from under

Fig. 1274.—The front of the right upper limb, showing the surface markings for the bones, arteries, and nerves.

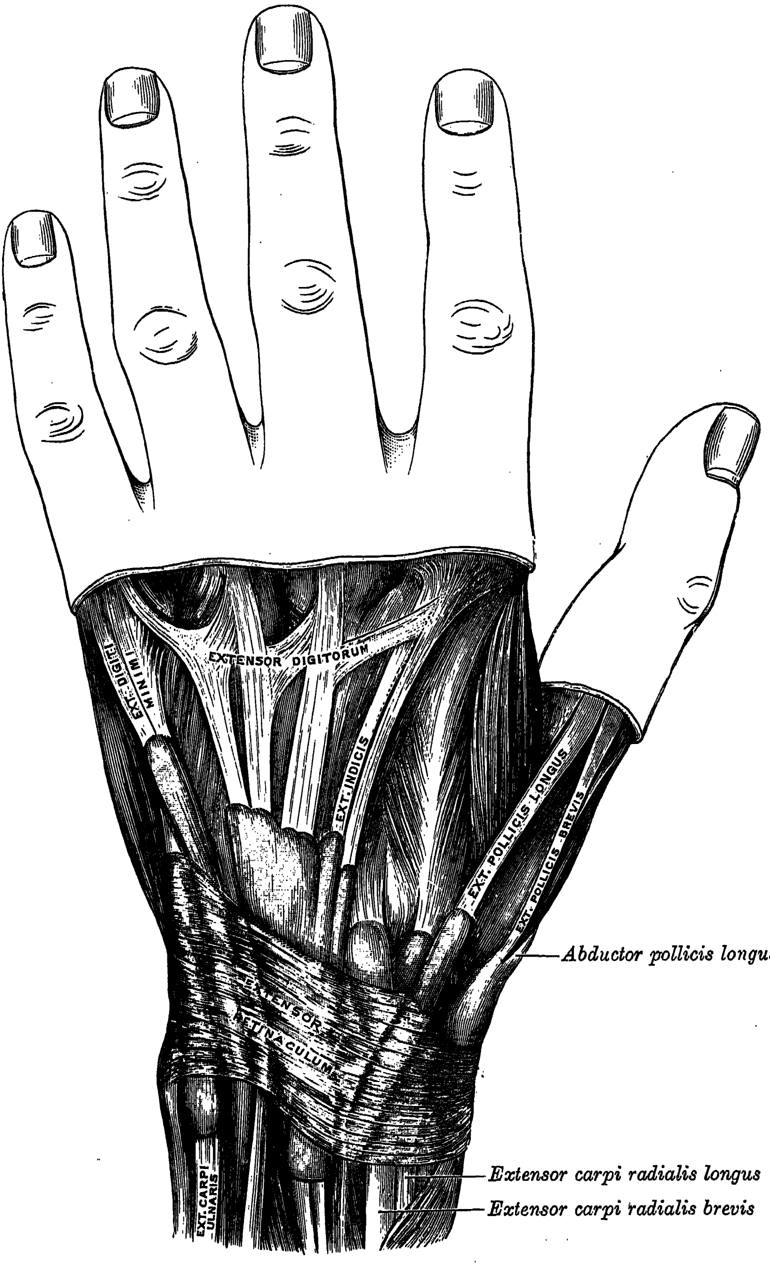


cover of the palmaris longus tendon. When that tendon is absent, the position of the nerve can be mapped out 1 cm. to the medial side of the flexor carpi radialis tendon. The *radial artery* commences opposite the neck of the radius on the medial side of the tendon of the biceps and runs downwards and laterally through the forearm to the wrist, where its pulsation can be felt in the interval between the flexor carpi radialis tendon medially, and the salient lower part of the anterior border of the radius laterally. It continues downwards across the anterior margin of the expanded lower end of the radius and then passes backwards, deep to the abductor pollicis longus and extensor pollicis brevis tendons, to gain the ' anatomical snuff-box,' where again its pulsation can be felt. The upper part of the line which represents the radial artery runs downwards across the medial part of the elevation produced by the brachioradialis and the superficial group of extensor muscles on the front of the forearm.

The *radial nerve* (fig. 1274) gives off its posterior interosseous branch at the level of the lateral epicondyle, 1 cm. to the lateral side of the tendon of the biceps and then runs vertically downwards. In the middle third of the forearm it lies along the lateral side of the radial artery, but in the lower third it inclines backwards to reach the ' anatomical snuff-box.' The *posterior interosseous nerve* can be represented by a line which passes downwards and backwards (across the elevation formed by the brachioradialis and the superficial group of the extensor muscles of the forearm), to reach the junction of the upper and middle thirds of a line joining the middle of the posterior aspect of the head of the radius to the dorsal tubercle on the lower end of the same bone. The lower two-thirds of this line roughly correspond to the rest of the course of the nerve.

The *flexor retinaculum* (transverse carpal ligament) can be outlined in the proximal part of the *hand*. Its lower border, concave downwards, can be indicated on the surface by a curved line joining the hook of the hamate bone to the crest of the trapezium ; its upper border by a curved line, concave upwards,

FIG. 1275.—The synovial sheaths of the tendons on the back of the wrist. (From a preparation by J. C. B. Grant.)



joining the pisiform bone to the tubercle of the scaphoid. The *extensor retinaculum* (dorsal carpal ligament) forms an oblique band, about 2 cm. broad, across the lateral and posterior aspects of the wrist. At its lateral extremity it is attached to the salient, lower end of the anterior border of the radius, above the styloid process and in front of the abductor pollicis longus tendon ; at its medial extremity, it reaches the medial side of the carpus and the tip of the styloid

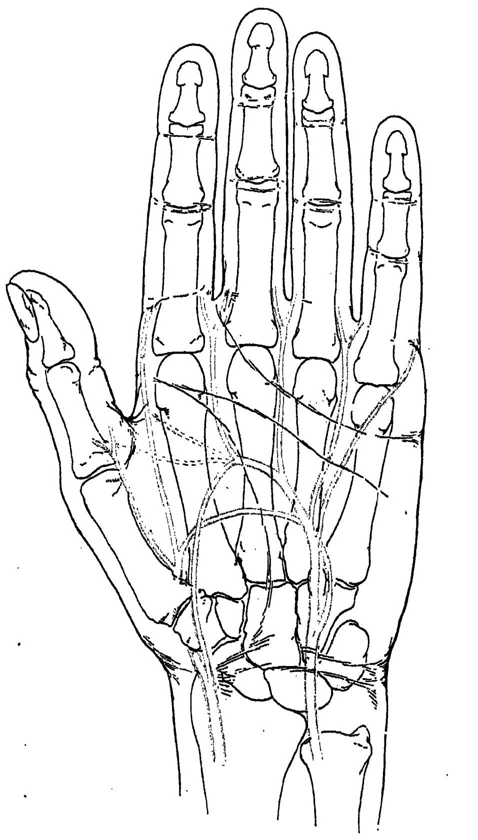
process of the ulna. The obliquity of the ligament, which is much higher on the lateral than it is on the medial side, is a very characteristic feature. The tendons which pierce or pass deep to the extensor retinaculum and their synovial sheaths are shown in fig. 1275.

The *line of the wrist joint* corresponds to a line, convex upwards, joining the styloid process of the radius to that of the ulna (Pl. VI, fig. 2).

The Hand

Surface landmarks.—The skin of the palm of the hand is marked by a number of creases, which, however, are of little value as points of reference. The *thenar eminence*, or *ball of the thumb*, is a fleshy elevation, produced by the abductor and the flexor pollicis brevis. The *hypothenar eminence* on the medial side of the palm is formed by the corresponding muscles of the little finger, but is not so prominent. Transverse skin creases cross the palmar aspects of the fingers in three situations; the most proximal crease is placed at the junction of the digit with the palm and lies nearly 2 cm. distal to the *metacarpophalangeal joint*; the intermediate crease lies opposite the *proximal interphalangeal joint*; and the distal crease is placed just *proximal* to the *distal interphalangeal joint*.

Fig. 1276.—The palm of the left hand, showing the positions of the skin creases and the bones, and the surface markings for the palmar arches.



The medial border of the hand is formed by the medial aspect of the hypothenar eminence, but the lateral border is formed by the dorsal aspect of the *metacarpal bone of the thumb*, which can be palpated throughout its whole extent (p. 363).

The lateral part of the dorsal aspect of the hand shows a fleshy elevation, which becomes more conspicuous when the thumb is adducted. It is caused by the *first dorsal interosseous muscle* and becomes firmly contracted when attempts are made to abduct the index finger actively against resistance.

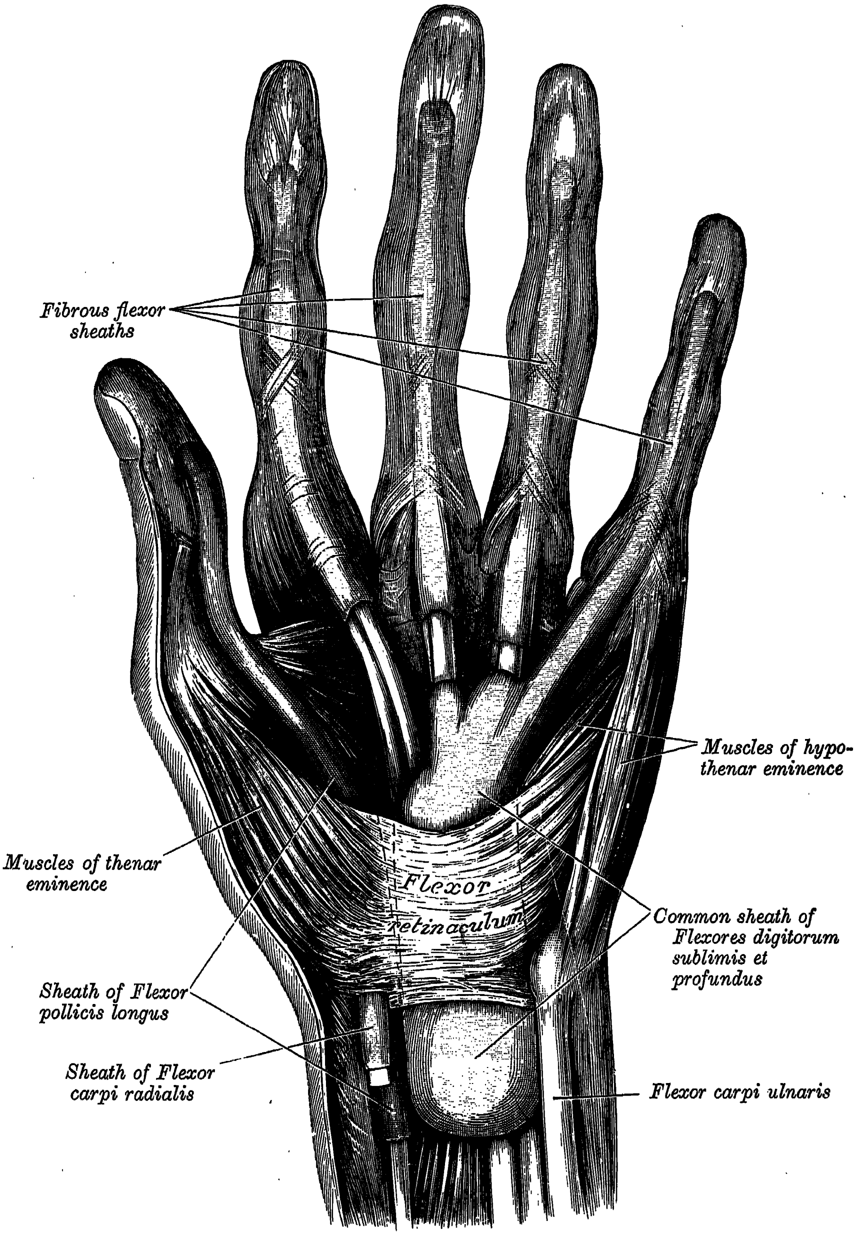
The *heads of the metacarpal bones* form the prominence of the knuckles, that of the middle finger being the most prominent. Their convex, palmar aspects can be felt on deep pressure over the fronts of the metacarpophalangeal joints and can be gripped between finger and thumb. On deep pressure over the distal aspect of the head of a metacarpal bone, the base of the corresponding proximal phalanx can be felt, and the line of the metacarpophalangeal joint can be determined on the back of the hand; its position must be noted both when the fingers are flexed and when they are extended. The dorsal aspects of the shafts of the metacarpal bones of the fingers can be felt indistinctly; only the distal portions of the third and fourth can be identified, because their proximal portions are obscured by the extensor tendons.

The *interphalangeal joints* can be felt on the dorsal aspect of the flexed finger,

just distal to the prominences caused by the heads of the proximal and middle phalanges.

The skin of the palm of the hand is tough and thick, and is covered with a thick layer of epidermis, but these characteristics are less marked on the thenar

FIG. 1277.—The synovial sheaths of the tendon on the front of the wrist and digits. (From a preparation by J. C. B. Grant.)



eminence. It is exceedingly sensitive and very vascular, but is devoid of hairs and sebaceous glands. Along the lines of the flexion creases of the digits, the skin is bound down by fibrous bands. The proximal segments of the fingers are joined to one another on the palmar aspect by folds of skin which constitute the 'web' of the fingers; these folds are placed opposite the centres of the proximal phalanges and their free margins are in line with the flexion creases at the roots of the fingers. Since the web is restricted to the palmar aspect, the fingers

appear shorter when viewed from in front than they do when viewed from behind. Over the fingers and thumb the skin is thinner, especially opposite the flexures of the joints, and over the distal phalanges ; it is disposed in numerous lines in consequence of the arrangement of the papillae which it contains. These lines form distinctive and permanent patterns, which can be used for purposes of identification. On the back of the hand and fingers, the skin is freely movable on the underlying parts.

Surface relations of other structures.—The *superficial palmar arch* is continuous with the ulnar artery opposite the lateral side of the pisiform bone. Its course can be marked out by a line drawn downwards in front of, or medial to, the hook of the hamate bone and then curved laterally, with a downward convexity, across the palm to the thenar eminence. The lowest part of its curve just reaches the level of the palmar surface of the extended thumb. The curvature of the vessel is subject to considerable variation, and it frequently forms the arc of a larger circle than it does in fig. 1276. The *deep palmar arch* can be represented by a horizontal line, 4 cm. long, drawn from a point just distal to the hook of the hamate bone ; it lies 1·2 cm. proximal to the superficial arch.

The *common synovial sheath of the flexor tendons of the digits* extends upwards into the forearm for 2·5 cm. above the flexor retinaculum (transverse carpal ligament) (fig. 1277). In this situation its medial border corresponds roughly to the lateral edge of the flexor carpi ulnaris tendon, and its lateral border to the medial edge of the flexor carpi radialis tendon. It becomes narrower as it passes behind the flexor retinaculum but it widens again in the palm. Its medial portion is continued distally along the lateral margin of the hypothenar eminence on the tendons for the little finger, but, with this exception, the common synovial sheath does not extend beyond the level of the palmar surface of the extended thumb. The *digital synovial sheaths* of the index, middle and ring fingers extend, in each case, from the base of the distal phalanx to the head of the corresponding metacarpal bone.

THE HEAD AND NECK

The Cranium

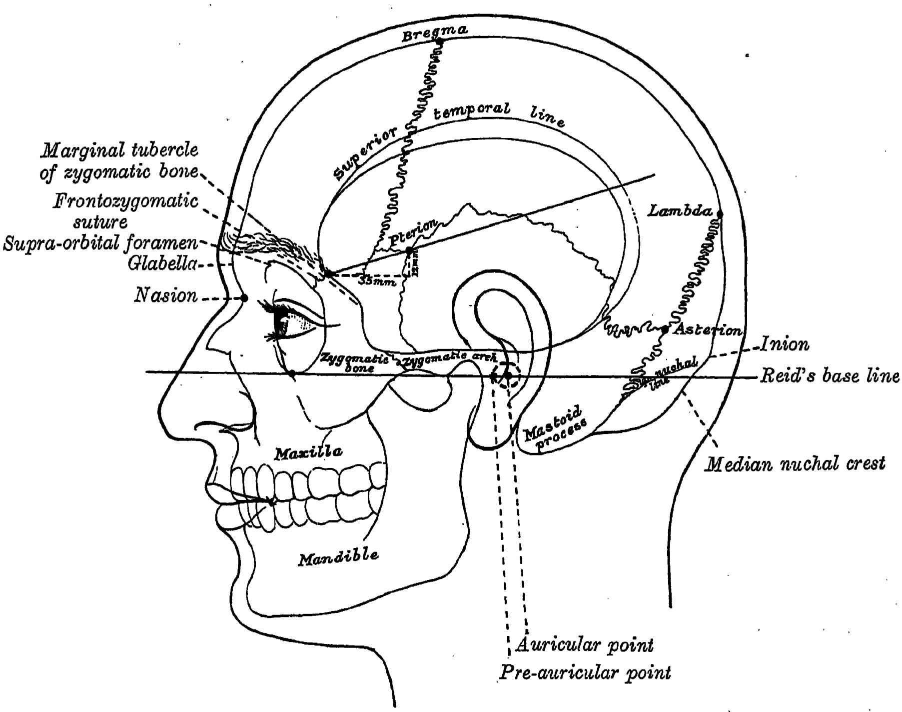
Surface landmarks (fig. 1278).—The *external occipital protuberance* is subcutaneous and can be felt at the upper end of the median *nuchal furrow,* which is plainly visible at the back of the neck ; it can be recognised without difficulty when it is approached from below. The *inion* is a point situated on the protuberance in the median plane. Above the protuberance the skull presents a backward convexity and the point of greatest curvature is named the *maximum occipital point.* Above and in front of the maximum occipital point an irregular depression, which corresponds to the *lambda* (p. 328), can be felt in the median plane.

The area between the two eyebrows overlies a slight elevation on the frontal bone which is termed the *glabella.* Below this elevation a well-marked depression can be seen and felt at the root of the nose ; it overlies the frontonasal suture and is termed the *nasion* (fig. 1278). Traced laterally, the glabella becomes continuous with the *superciliary arch,* which is a rounded, bony ridge placed a short distance above, and parallel with, the supra-orbital margin. The *frontal eminence* lies above and lateral to the superciliary arch and, although its size is subject to considerable variation, it can be felt without much difficulty. The *supra-orbital margin* can be recognised along the line of the eyebrow. Rounded in its medial third, it becomes sharper in its lateral part and the junction between the two portions is marked by the *supra-orbital notch,* which can be felt, when present, 2·5 cm. from the median plane. The *lateral margin of the orbital opening* is a sharp edge, which can easily be felt and is formed by the frontal process of the zygomatic bone. The lateral surface of this process can be felt through the skin, and the *frontozygomatic suture* (fig. 1278) can be recognised as a slight, irregular depression at its upper end. The posterior border of the *zygomatic process of the frontal bone,* although partially obscured

by the attachment of the temporal fascia, can be traced upwards from the fronto-zygomatic suture into the *temporal line*, which curves upwards and backwards to become continuous with the superior of the two temporal lines on the parietal bone. Above and behind the auricle this line turns downwards and forwards to become continuous with the *supramastoid crest*. The *parietal eminence* lies above the posterior part of the superior temporal line and can be recognised most satisfactorily when the hand is placed flat on the side of the head. The line joining the two parietal eminences is the greatest transverse diameter of the head.

The *mastoid process* is hidden by the lobule and the lower part of the concha of the auricle. Its anterior border and lateral aspect can be palpated but its tip and posterior border are obscured by the attachment of the sternomastoid

FIG. 1278.—A side view of the head, showing the surface relations of the bones.



and splenius capitis muscles. At its base, about 3 cm. to 4 cm. above its tip, the *supramastoid crest* can be felt and traced upwards and backwards into the superior temporal line.

Immediately in front of the upper part of the tragus the *superficial temporal artery* crosses the posterior root of the zygoma at the *pre-auricular point*, and its pulsation can be felt in this situation. Just in front of the pre-auricular point the two *roots of the zygoma* unite and the arch can be traced forwards to the prominence of the cheek bone; its upper border is obscured by the temporal fascia, and its lower border, by the masseter muscle. The posterior root of the zygoma is continuous with the supramastoid crest, but the continuity is hidden by the auricle. The upper border of the zygomatic arch can be traced forwards till it meets the frontal process of the zygomatic bone at the *jugal point* (p. 329).

If the hand is placed flat on the side of the head, the contraction of the temporal muscle can be appreciated when the teeth are clenched. Owing to the dense, unyielding character of the temporal fascia, the muscular elevation is limited to the region immediately within the superior temporal line.

Although the *pterion* (p. 251) does not form a visible or a palpable landmark, it is convenient at this stage to indicate that its centre corresponds to a

point, approximately 3·5 cm. or less behind, and 1·5 cm. above, the fronto-zygomatic suture (fig. 1278).

The skin of the scalp is intimately connected to the underlying epicranial aponeurosis by numerous fibres, an arrangement which makes it impossible to pick up a fold of the skin in this situation between the fingers and thumb. It can however be moved about with the epicranial aponeurosis on the skull, as the subaponeurotic layer of the scalp is loose in texture.

Surface relations of the Brain.—The *superomedial margin of the cerebral hemisphere* corresponds to a paramedian line drawn from a point a little above and a little lateral to the inion forwards to a point just above and lateral to the nasion. The *superciliary margin* of the hemisphere can be represented by a line which arches upwards and laterally a little above the eyebrow, commencing at the anterior end of the superomedial margin and reaching the zygomatic process of the frontal bone ; from the latter point the line of the margin ascends to the pterion. The *temporal pole* lies opposite to a line drawn, with a forward convexity, from the pterion to the middle of the upper border of the zygomatic arch. The *inferolateral margin* of the cerebral hemisphere corresponds to a line drawn backwards from the lower limit of the temporal pole just above the upper border of the zygomatic arch to cross the auricle a little above the external auditory meatus (fig. 1279). It then descends slightly to reach the posterior end of the superomedial margin.

The *central sulcus* can be represented by a line which commences on the superomedial margin of the hemisphere, 1·2 cm. behind its mid-point (or 1·2 cm. behind the mid-point of the line which joins the nasion to the inion in the median plane). From there it runs, with a somewhat sinuous course, downwards, forwards and laterally, making an angle of 70° with the median plane, and terminates 5 cm. vertically above the pre-auricular point. The *motor area* of the cortex occupies a strip, 1 cm. broad, in front of the central sulcus, and the somaesthetic area, a similar strip behind it.

The *lateral sulcus* ends opposite to the pterion by dividing into its three rami. Its *posterior ramus* (fig. 1279) can be represented by a line drawn backwards with an upward inclination from the pterion ; it passes just below the lower end of the central sulcus and, about 7 cm. from the pterion, turns upwards to end under the parietal eminence. The *superior temporal sulcus* lies about 1 cm. below the posterior ramus of the lateral sulcus and exhibits a similar curve. The *higher auditory centre* lies in the area between these two sulci, immediately behind the lower end of the central sulcus. The anterior and middle parts of the *inferior parietal lobule* (supramarginal and angular gyri) lie under the parietal eminence and surround the upturned ends of the posterior ramus of the lateral sulcus and the superior temporal sulcus respectively. The *higher visual centre* is situated partly on the lateral surface of the hemisphere, immediately in front of the occipital pole, but the larger part of the area lies on the medial surface.

The *inferior cornu of the lateral ventricle* lies immediately below the line which represents the superior temporal sulcus. A needle, introduced at a trephine hole the centre of which is 3 cm. behind and 3 cm. above the middle of the external auditory meatus, and passed in the direction of the tip of the opposite auricle, enters the inferior cornu at a distance of 5 cm. from the surface. In X-ray photographs of the skull, when air has been injected into the ventricles, the uppermost part of the helix rises just above the floor of the inferior cornu, the anterior end of which lies about 2 cm. vertically above the pre-auricular point. The *cerebellum* occupies the area immediately below the line of the transverse sinus (*vide infra*).

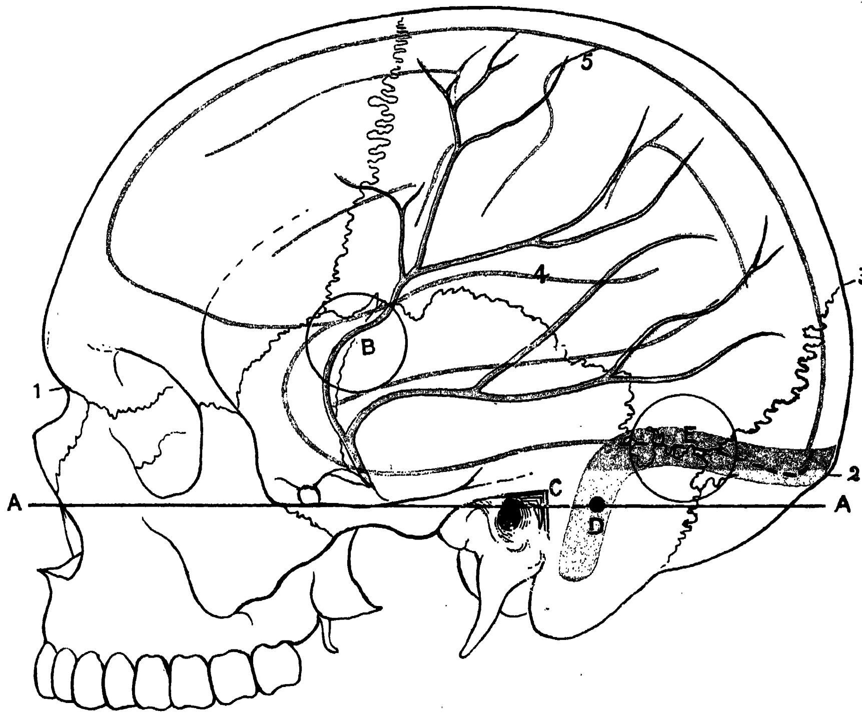
Surface relations of other structures.—The *superior sagittal sinus* commences at the glabella and can be represented by a line drawn upwards and backwards in the median plane and continued downwards, posteriorly, to the inion. Narrow in front, the line widens as it passes backwards until, near its termination, it may be 1·2 cm. broad. The *transverse sinus* (fig. 1279) commences at the inion and runs laterally, with a slight upward convexity, along the infero-lateral margin of the cerebral hemisphere. Opposite the base of the mastoid process it becomes the *sigmoid sinus*, which passes downwards close to the posterior border of the process to a point 1·2 cm. from its tip.

The lines which represent the edges of these sinuses should be at least 1·2 cm. apart.

The *middle meningeal artery* (fig. 1279) enters the skull opposite a point a little in front of the pre-auricular point and can be represented by a line drawn forwards and slightly upwards to a second point, 2 cm. above the middle of the zygomatic arch. There the artery divides and its *anterior division* runs upwards and slightly forwards to the pterion and then upwards and backwards (fig. 1279) in the direction of the mid-point between the inion and the nasion. The *posterior division* runs backwards and upwards towards the lambda.

The *trigeminal* (semilunar) *ganglion* lies at a distance of 4·5 cm. to 5 cm. from the lateral aspect of the head, a little in front of the pre-auricular point. The

FIG. 1279.—The relations of the brain and the middle meningeal artery to the surface of the skull.



1. Nasion. 2. Inion. 3. Lambda. 4. Lateral cerebral sulcus. 5. Central sulcus. AA. Reid's base-line, which passes through the lower margin of the orbital opening and the upper margin of the external auditory meatus. B. Point for trephining over the anterior branch of the middle meningeal artery. C. Suprameatal triangle. D. Sigmoid sinus. E. Point for trephining over the transverse sinus, exposing dura mater of both cerebrum and cerebellum. The outline of the cerebral hemisphere is indicated in blue; the course of middle meningeal artery in red.

cavernous sinus lies close to the medial side of the ganglion but extends beyond it both in an upward and in a forward direction.

The *hypophyseal fossa* is traversed by a straight line joining the nasion to the inion at a depth of 6 cm. to 7 cm. from the nasion (Pl. I, fig. 1).

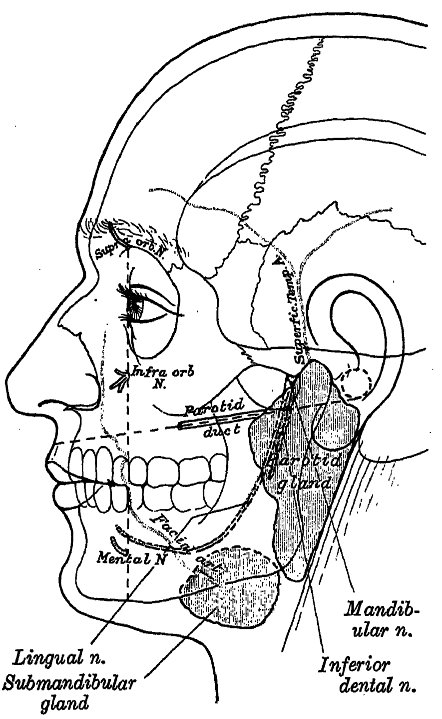
THE FACE

Surface landmarks.—The *bridge of the nose* is formed by the articulation between the two nasal bones; it ends above at the nasion, which is often termed the root of the nose. The margins of the bony *anterior nasal aperture* can be felt through the skin above the bulging ala nasi. Sharp and distinct laterally, the margin is rounded inferiorly, but, in the median plane, the *anterior nasal spine* can be recognised on upward pressure over the posterior portion of the free part of the nasal septum.

The prominence of the cheek, which lies below and lateral to the eye, is formed by the *zygomatic bone* (fig. 1280). The lateral surface of the bone can readily be felt through the skin ; it can be traced upwards into the frontal process, backwards into the zygomatic arch and forwards into the zygomatic process of the maxilla. The postero-inferior border of the bone is obscured by the masseter muscle when the teeth are clenched, but it can be determined when the muscle is relaxed and can be traced into continuity with the lower border of the zygomatic process of the maxilla, which can be felt without difficulty above the crown of the first upper molar tooth. The *infra-orbital margin* can be examined both in its lateral, zygomatic, and in its medial, maxillary portion. Below the orbit, the anterior surface and the alveolar process of the maxilla can be recognised.

Almost the whole of the outer surface of the *mandible* can be felt through the skin, although the coronoid process is hidden by the zygomatic bone and most of the ramus is covered with the masseter muscle. The *angle* can be identified below and in front of the lobule of the auricle and can be traced upwards into the posterior border of the ramus and forwards into the lower border of the body of the bone. The outer aspect of the *body* can be palpated throughout the whole of its extent and the projection of the mental protuberance is easily identified. The *condyloid process* lies immediately in front of the lower part of the tragus (fig. 1280) ; it is partly obscured by the parotid gland and the temporomandibular ligament, but it can be felt to pass forwards and downwards when the mouth is opened. The *masseter muscle* covers most of the ramus : its posterior border corresponds to a line drawn from the lower border of the zygomatic arch, just in front of the condyle, to the angle of the mandible ; its anterior border, to a line drawn downwards and backwards from the postero-inferior border of the zygomatic bone, vertically below the lateral margin of the orbit, to a point on the lower border of the mandible, 2·5 cm. in front of the angle. The outline of the muscle can be determined when the teeth are clenched, and the *parotid duct* can be rolled across its anterior border a little below the zygomatic bone. The *coronoid process* of the mandible is not easy to examine, although the lower part of its anterior border can readily be felt through the inside of the mouth. If a finger tip is placed in the angle between the masseter muscle and the zygomatic bone the anterior border of the coronoid process can be felt indistinctly when the mouth is opened.

FIG. 1280.—An outline of the side of the face, showing the chief surface markings.



The *oral fissure* lies opposite the cutting edges of the upper incisor teeth, and the *angle of the mouth* lies just in front of the first premolar tooth.

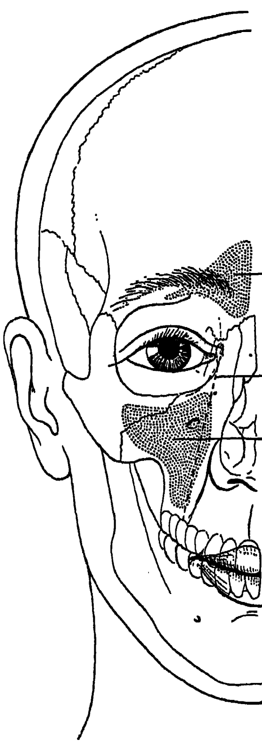
The pulsation of the *facial artery* can be felt immediately in front of the lower end of the anterior border of the masseter muscle (fig. 1280), and again opposite the angle of the mouth. In the latter situation the cheek must be gripped lightly between a finger placed inside the mouth and the thumb placed on the skin surface ; the artery will be identified 1·2 cm. or more from the angle of the mouth. When the lateral part of the lip is gripped in a similar manner, the pulsation of the corresponding *labial artery* can be felt from the mucous surface at a distance of 0·5 cm. from its free margin.

The skin of the face is thin and freely movable, except over the alæ and apex of the nose, where it is thicker and firmly adherent to the deeper tissues.

The surface anatomy of the mouth (pp. 1262 and 1284), the eye (p. 1184) and the ear (pp. 1190 and 1196) have already been described.

Surface relations of other structures.—The *parotid gland* (fig. 1280) occupies the depression behind the ramus of the mandible and extends forwards on to the masseter muscle. Its anterior border can be represented by a line drawn downwards and forwards from the upper border of the mandibular condyle to a point a little above the centre of the masseter muscle, and then downwards and backwards to a point a little behind and a little below the angle of the mandible. Its upper border lies below the external auditory meatus and is concave upwards and backwards ; it corresponds to a curved line drawn downwards and backwards from the upper border of the condyle, across the lobule of the auricle, to the mastoid process. Its posterior border follows a straight line joining the ends of its upper and anterior borders. The *parotid duct* (p. 1442) may be represented by rather less than the middle third of a line drawn from the lower border of the concha to midway between the ala of the nose and the red margin of the upper lip ; its terminal part runs almost horizontally medially and opens into the vestibule of the mouth on a small papilla opposite to the second upper molar tooth.

Fig. 1281.—An outline of the bones of the face, showing the positions of the frontal and maxillary sinuses.



The *facial nerve* enters the parotid gland as soon as it emerges from the stylomastoid foramen, which lies about 2 cm. deep to the middle of the anterior border of the mastoid process. In the gland it runs laterally and forwards and in this part of its course it can be indicated by a short horizontal line drawn on the upper part of the lobule of the auricle (fig. 1284). Its zygomatic and buccal branches pass forwards across the neck of the mandible.

The *facial artery* (fig. 1280) enters the face at the lower part of the anterior border of the masseter muscle (p. 1442). It corresponds to a line drawn from this point upwards and forwards to a point 1·2 cm. lateral to the angle of the mouth, and thence upwards to the medial angle of the eye, curving forwards almost to the ala of the nose. The *anterior facial vein* can be represented by a line drawn downwards and backwards from the medial angle of the eye to the lower part of the anterior border of the masseter muscle, just behind the facial artery.

The *mandibular notch* can be represented by a line, concave upwards, which commences at the front of the condyloid process and curves forwards to the anterior part of the zygomatic arch (fig. 1280). It is about 1·2 cm. deep and is concealed by the masseter muscle. The *mandibular nerve*, as it descends from the foramen ovale, lies opposite the posterior part of the mandibular notch at a distance of 4 cm. from the surface. The *auriculotemporal nerve* corresponds to a line drawn backwards from the mandibular nerve across the neck of the mandible and then upwards across the pre-auricular point behind the superficial temporal artery. The *inferior dental nerve* corresponds to a line drawn from the mandibular nerve to the centre of the masseter muscle. Its terminal, *mental*, branch emerges from the *mental foramen*, which lies midway between the upper and

lower borders of the mandible, in the adult, and vertically below the interval between the premolar teeth. The *lingual nerve* (fig. 1280) lies deep to the mandible in its whole course, and can be represented by a line drawn downwards and forwards from the mandibular nerve to a point a little below and behind the last molar tooth. With a finger placed inside the mouth the nerve can be pressed against the bone in this situation. Thence the line is continued forwards, with an upward concavity, along the body of the mandible.

Where the *maxillary nerve* crosses the pterygopalatine fossa, it lies about 5 cm. deep to the surface, opposite to, or just behind, the jugal point (p. 1439). Continuing forwards, it emerges, as the *infra-orbital nerve*, from the *infra-orbital foramen*, which lies vertically below the supra-orbital notch and 1 cm. below the lower margin of the opening of the orbit.

The cutaneous distribution of the divisions of the trigeminal nerve on the face and scalp is shown in fig. 949.

The *pharyngotympanic tube* (auditory tube), which lies deep to the mandibular nerve, is situated opposite to the posterior part of the mandibular notch, at a distance of 4·5 cm. from the surface.

The *tonsil* lies behind the third molar tooth and can be represented as an oval area over the lower part of the masseter muscle, i.e. just above and in front of the angle of the mandible (fig. 1284).

The *frontal sinus* (p. 1162) can be represented on the surface as a triangular area above and lateral to the root of the nose (fig. 1281). The angles of the triangle are formed by (1) the nasion, (2) a point 2·5 cm. above the nasion and (3) the junction of the medial third with the rest of the supraorbital margin. The *maxillary sinus* (p. 1163) extends upwards to the floor of the orbit, and the infra-orbital margin may be taken to represent its roof. Its inferior limit corresponds to a line drawn across the alveolus of the maxilla, opposite the second premolar and the molar teeth, on a level with the lower border of the ala of the nose (fig. 1281).

The Neck

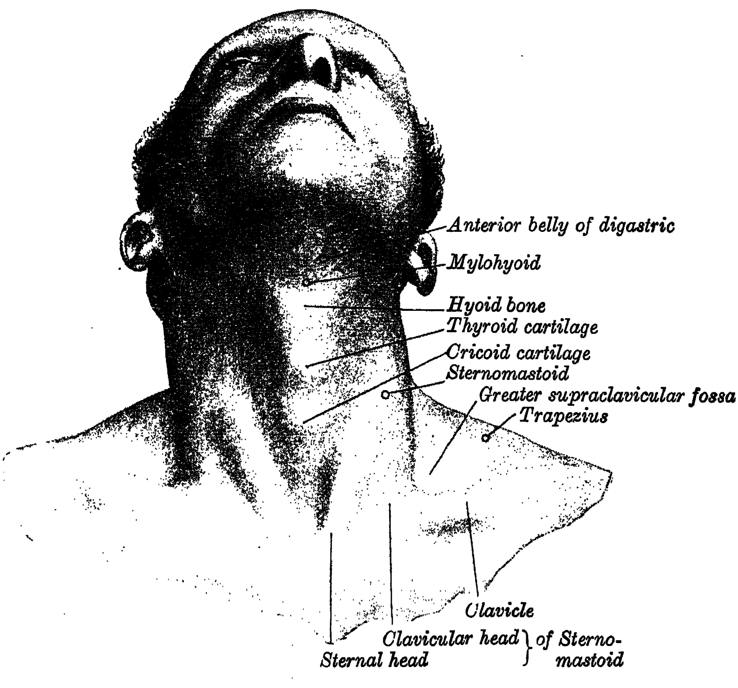
Surface landmarks.—The *sternomastoid muscle* (figs. 1282, 1283) forms a prominent, visible landmark, which intervenes between the regions of the anterior and posterior triangles of the neck. When the head is rotated to one side and tilted forwards, the muscle of the opposite side is rendered tense. Below, the sternal head stands out as a clean-cut cord crossing the sternoclavicular joint, but the clavicular head, which extends for one-third of the way along the clavicle, is not so prominent. The anterior border, which is thick and rounded, extends upwards from the sternal head to the anterior border of the mastoid process ; the posterior border, which is difficult to feel, ascends from the junction of the medial and middle thirds of the clavicle to the mid-point between the mastoid process and the inion. Inferiorly the sternal heads are separated by the *suprasternal notch*, a surface depression limited below by the upper border of the manubrium sterni and, on each side, by the prominent *sternal end of the clavicle.*

In the median plane the *laryngeal prominence* (fig. 1284), or Adam's apple, can be felt easily, and can be seen in men although it may not always be visible in women. The anterior portions of the upper borders of the two thyroid laminæ can be palpated and the thyroid notch can be identified. Above the thyroid cartilage the skin is drawn backwards below the chin to the *hyoid bone*, the body of which can be felt above and behind the laryngeal prominence. When the throat is gripped between the finger and thumb, just above the thyroid cartilage, and the opposing digits are moved upwards and downwards, the *greater cornu* of the hyoid bone can be recognised and traced backwards to its tip. Below the thyroid cartilage in the median plane the *arch of the cricoid cartilage* can be felt ; it is on a level with the lower part of the *cricoid lamina*, which lies opposite the body of the sixth cervical vertebra. The depression between the arch of the cricoid and the thyroid prominence corresponds to the cricothyroid ligament. Below the arch of the cricoid the upper rings of the trachea can be made out, but they are partly obscured by the isthmus of the thyroid gland.

When the finger tips are placed on the anterior border of the sternomastoid muscle below the level of the laryngeal prominence, the pulsation of the *common carotid artery* can be appreciated, especially if pressure is exerted backwards and laterally. Above the level of the laryngeal prominence and below the angle of the mandible no difficulty is experienced in feeling the pulsation of the *external carotid artery,* which tends to emerge from under cover of the muscle in this part of its course.

Approximately midway between the tip of the mastoid process and the angle of the mandible, the tip of the *transverse process of the atlas* offers resistance to deep pressure through the parotid gland. The tips of the other cervical transverse processes are nearer to the median plane; with the exception of the sixth, they cannot be palpated. The *carotid tubercle* on the transverse process of the sixth cervical vertebra lies at the level of the arch of the cricoid cartilage,

FIG. 1282.—A front view of the neck.



about 3 cm. from the median plane. It lies behind the common carotid artery and the sternomastoid muscle, but it can often be recognised.

Behind the sternomastoid muscle the position of the *posterior triangle* of the neck may be indicated by a shallow depression (fig. 1284) which extends from the back of the head to the middle third of the clavicle and is always deepest in its lower part [greater supraclavicular fossa]. The anterior border of the *trapezius,* which forms its posterior boundary, can be seen in muscular subjects, especially when resistance is opposed to elevation of the shoulder. In the lower part of the triangle, the inferior belly of the *omohyoid muscle* can often be seen in thin subjects; it forms an oblique ridge, running medially, forwards and upwards, which appears and disappears, as the muscle contracts and relaxes during speech.

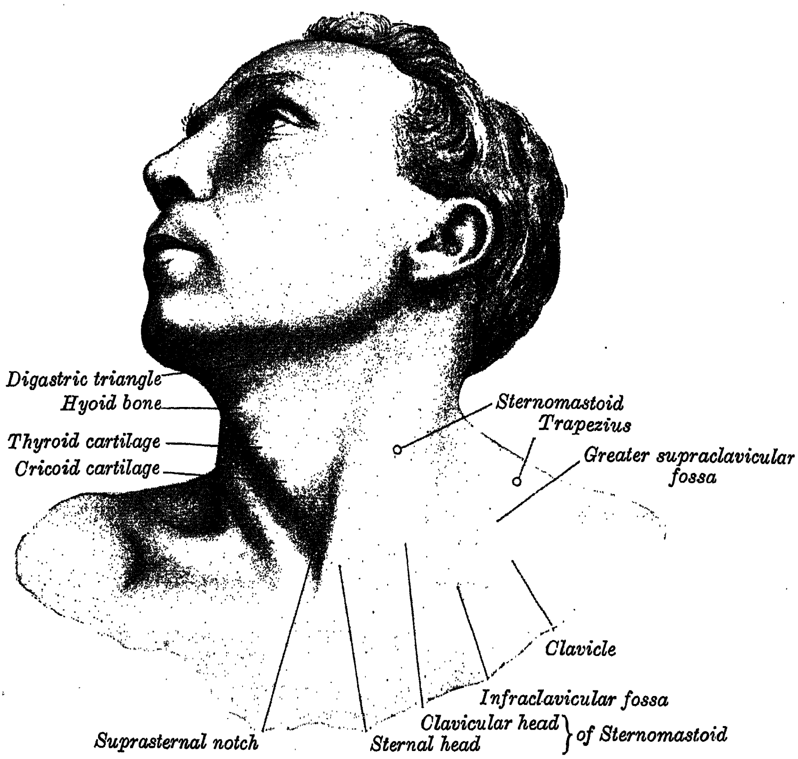
When the arm is by the side the trunks of the *brachial plexus* can be felt as a bunch of tense cords in the angle between the clavicle and the sternomastoid muscle. The *subclavian artery* is the only other important structure which can be identified in the posterior triangle of the neck. The pulsation of its terminal part can be recognised when pressure is exerted downwards behind the middle of the clavicle, and, in this situation, the artery can be compressed against the upper surface of the first rib.

At the back of the neck the nuchal furrow (p. 1438) overlies the tips of the *spines* of the cervical vertebræ. At its lower end the spine of the *seventh cervical vertebra* can be seen and can be identified from the fact that it is the highest, and sometimes the only, visible projection in this region. The spines of the other cervical vertebræ can be felt indistinctly and that of the *axis* lies about 5 cm. below the inion (p. 1438). The muscular elevation on each side of the nuchal furrow is produced by the semispinalis capitis, covered with the splenius capitis (in part) and the trapezius.

The skin of the front and side of the neck is thin and easily moved about over the underlying structures. At the back of the neck it is thicker and less movable, being bound down by numerous fibres to the deeper tissues.

Surface relations of other structures.—The *common carotid artery* (fig. 1284) can be represented by a broad line drawn upwards and backwards from the

FIG. 1283.—An anterolateral view of the head and neck.



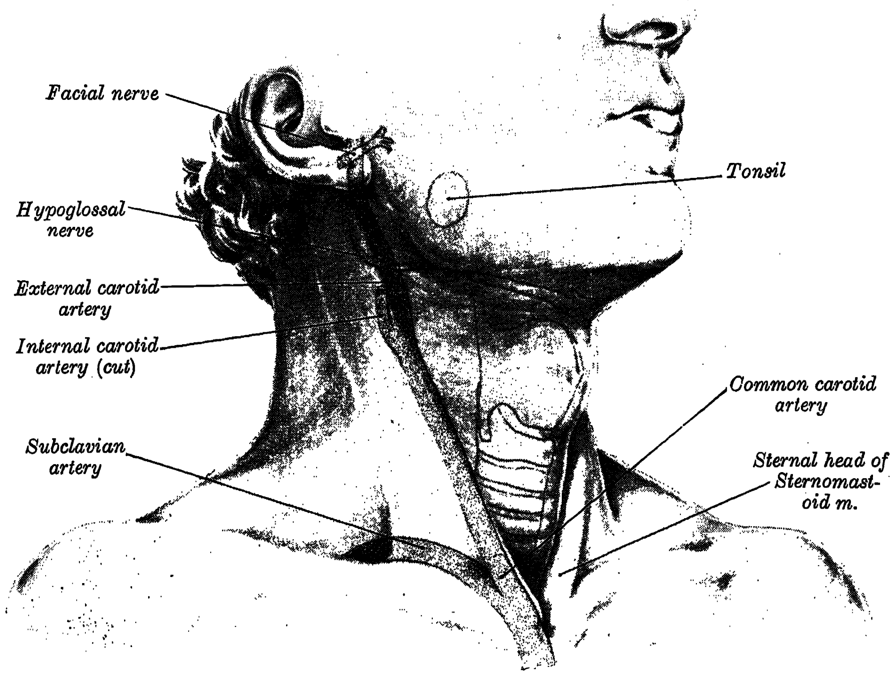
sternoclavicular joint, along the anterior border of the sternomastoid as far as the level of the upper border of the thyroid cartilage. From this point the *external carotid artery* ascends to a point midway between the tip of the mastoid process and the angle of the mandible. It should be represented by a broad line, which is gently convex forwards in its lower half and as gently concave forwards in its upper half. The origin of the *lingual artery* lies opposite the tip of the greater cornu of the hyoid bone, and its initial upward loop is crossed by the hypoglossal nerve. The *internal carotid artery* corresponds to a broad line drawn upwards from the termination of the common carotid artery to the posterior border of the condyle of the mandible.

The *internal jugular vein* (fig. 1285) can be represented by a broad line drawn downwards from the lobule of the ear to the medial end of the clavicle; its lower bulb lies behind the little depression [lesser supraclavicular fossa] which marks the interval between the sternal and the clavicular heads of the sternomastoid.

As the glossopharyngeal, vagus, accessory and hypoglossal nerves lie at the base of the skull, their position can be indicated opposite the lower and anterior

part of the tragus. The *glossopharyngeal nerve* corresponds to a line, drawn downwards and forwards from that point, passing above the angle of the mandible and then continuing forwards for a short distance along the lower border of the mandible. The *vagus nerve* can be represented by a line drawn downwards from the same point, along the medial side of the internal jugular vein, to the medial end of the clavicle. The *accessory nerve* (fig. 1285) corresponds to a line which passes downwards from the lower and anterior part of the tragus to the tip of the transverse process of the atlas. From the latter the line is continued downwards and backwards, across the elevation produced by the sternomastoid and the depression corresponding to the posterior triangle of the neck, to a point on the anterior border of the trapezius, 6 cm. above the clavicle. The *hypoglossal nerve* follows the same line as the vagus until it

FIG. 1284.—The surface relations of some of the important structures in the face and neck.



reaches a point a little above and a little behind the tip of the greater cornu of the hyoid bone. It then bends sharply forwards and curves upwards to a point approximately midway between the angle and the symphysis of the mandible when the head is tilted backwards.

The *external jugular vein* can be marked out by a line drawn downwards from a point a little below and behind the angle of the mandible to reach the clavicle just lateral to the posterior border of the sternomastoid. Behind the clavicle it joins the *subclavian vein*, which corresponds to a short but broad line, drawn along the clavicle from a little medial to its mid-point to the medial edge of the clavicular head of the sternomastoid (fig. 1285).

The *subclavian artery* (fig. 1284) can be represented by a broad line, convex upwards, drawn from the sternoclavicular joint to the middle of the lower border of the clavicle ; the summit of the curve lies 2 cm. above the clavicle.

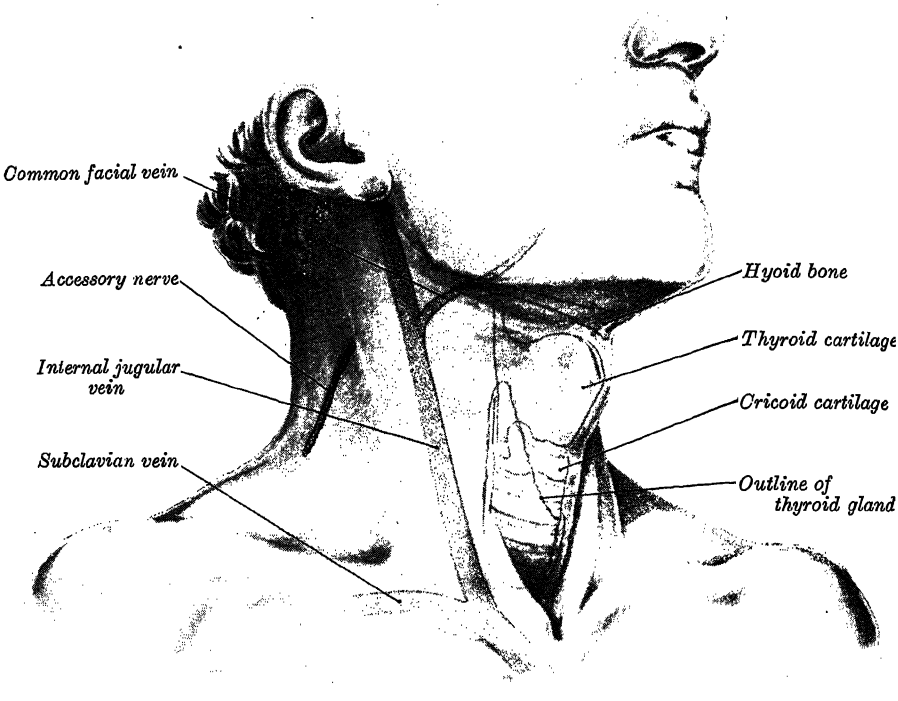
The *scalenus anterior* lies entirely behind the sternomastoid ; its lateral border corresponds to a line drawn from a point, at the level of the upper border of the thyroid cartilage and 2·5 cm. from the median plane, downwards and laterally to the lower border of the clavicle at the junction of its medial and

middle thirds ; its medial border, to a line drawn from a point, opposite the arch of the cricoid cartilage, 2·5 cm. from the median plane, downwards and laterally to a second point, 1 cm. medial to the lower end of the lateral border.

The *supraclavicular part of the brachial plexus* lies in the triangular area bounded by the upper border of the clavicle, the lateral border of the scalenus anterior and a line drawn from the arch of the cricoid cartilage to the middle of the clavicle.

The *submandibular salivary gland* (fig. 1280) can be represented on the surface as an oval area, lying partly above and partly below the posterior half of the lower border of the mandible. Its upper limit commences at the angle of the mandible and passes forwards with a gentle convexity upwards to reach a

FIG. 1285.—The side of the neck, showing some of the important surface landmarks and surface markings.



point midway between the angle and the symphysis ; it rarely extends upwards more than 1·5 cm. above the lower border of the bone. Its lower limit can be indicated by a line with a downward convexity, which reaches as low as the greater cornu of the hyoid bone.

The *thyroid gland* has such a characteristic shape that, when the position of the isthmus has been determined, there should be no difficulty about the outline of the lobes. The upper border of the isthmus corresponds to a line, 1·5 cm. long, drawn across the trachea, 1 cm. below the arch of the cricoid cartilage ; its lower border, to a similar line, 2 cm. lower down. The broad, lower pole of the lobe extends downwards for 1 cm. from the lateral end of the lower border of the isthmus and then laterally, with a downward convexity, for 2 cm. to 2·5 cm. The narrow, upper pole of the lobe lies on a level with the laryngeal prominence a little in front of the anterior border of the sternomastoid. Lines joining the upper pole to the lateral end of the upper border of the isthmus and to the lateral end of the lower pole complete the outline of the lobe of the gland (fig. 1285).

The level of the *vocal folds* can be indicated on the anterior border of the thyroid cartilage a little above its mid-point.

The *cervical plexus* lies behind the internal jugular vein above the level of the thyroid cartilage. Its cutaneous branches become superficial along the posterior border of the sternomastoid muscle. The *anterior cutaneous nerve of the neck* corresponds to a line drawn across the muscle from the mid-point on its posterior border. The *great auricular* and *lesser occipital nerves* appear at a slightly higher level; the former runs upwards towards the lobule of the auricle, while the latter ascends along the posterior border of the muscle to reach the scalp. The *descending cutaneous branches* emerge below the anterior cutaneous nerve and diverge as they run downwards. The *phrenic nerve* lies behind the sternomastoid and the internal jugular vein; it corresponds to a line drawn from a point, 3·5 cm. from the median plane and on a level with the upper border of the thyroid cartilage, downwards to the sternal end of the clavicle.

The *sympathetic trunk* can be represented by a line drawn from the sterno-clavicular joint to the posterior border of the condyle of the mandible. The *superior cervical ganglion* lies on this line, between the tip of the transverse process of the atlas vertebra and the greater cornu of the hyoid bone: the *middle cervical ganglion*, opposite, or just below, the arch of the cricoid cartilage: and the *inferior cervical ganglion*, about 3 cm. above the sterno-clavicular joint.

The *cervical pleura* (fig. 1291) rises above the clavicle and the sternal end of the first rib. It can be represented by a line, convex upwards, drawn from the sternoclavicular joint to the junction of the medial and middle thirds of the clavicle. The summit of the curve lies about 3·5 cm. above the clavicle. The same line represents the outline of the *apex of the lung*.

THE BACK

Surface landmarks.—A median furrow overlies the tips of the spines of the vertebræ; its upper or nuchal part has already been described (p. 1446). In the upper thoracic region the furrow is shallow, and elevations produced by the tips of the spines of the seventh cervical and first (and sometimes the second) thoracic vertebræ can be seen and felt. The identification of the remaining thoracic spines is not easy, even in a thin subject when the trunk is fully flexed, owing to the manner in which they overlap one another in the midthoracic region. The third thoracic spine lies opposite the root of the scapular spine (p. 1428) and the seventh lies opposite the inferior angle of the scapula, provided that the arm is at rest by the side. The twelfth thoracic spine lies opposite the mid-point of a line drawn from the inferior angle of the scapula to the iliac crest.*

The median furrow is deepest at the small of the back (fig. 1286), but it widens out below into a flattened, triangular area, the apex of which lies at the commencement of the natal cleft (p. 1469) and corresponds to the third sacral spine. The two basal angles of this triangular area are formed by two symmetrically placed dimples, which overlie the *posterior superior iliac spines*, and the line joining them passes through the *second sacral spine*. It should be observed that the posterior superior spine lies over the centre of the sacro-iliac joint.

On each side the median furrow is bounded by a broad elevation produced by the *sacrospinalis muscle* (fig. 1286). The lateral border of this elevation crosses the ribs at their angles, passing medially as it ascends. The identification of the upper ribs on the dorsal aspect is very difficult, but the *eighth rib*, which lies immediately below the inferior angle of the scapula, can be recognised with certainty. Below the eighth, the ninth, tenth and eleventh, and the twelfth when it projects beyond the sacrospinalis, can all be identified.

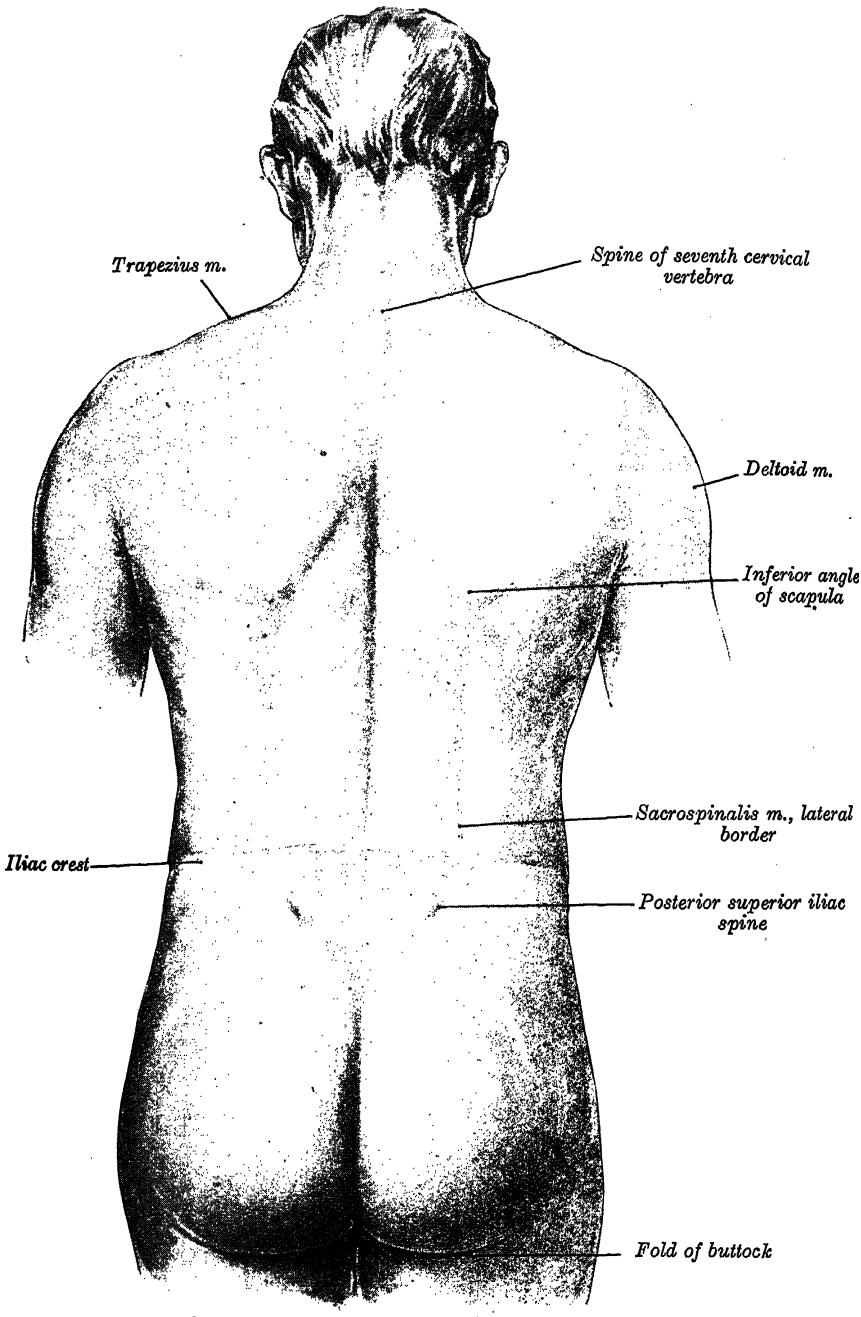
The surface landmarks of the *scapula* have been described on p. 1428.

At the lower part of the back the *iliac crest* can be palpated throughout its whole length, and can be traced backwards and upwards from the anterior

* Arthur Robinson and E. B. Jamieson, *Surface Anatomy*, London, 1928.

superior spine (p. 1465) to its *highest point*, which lies behind the mid-point of the crest and opposite the interval between the spines of the third and fourth lumbar vertebræ. From these the crest can be traced downwards and medially

FIG. 1286.—The surface anatomy of the back.



to the posterior superior iliac spine (p. 1449), which lies 5 cm. from the median plane. The *tubercle* of the crest lies 5 cm. or more behind the anterior superior spine, at the widest part of the pelvis and is on a level with the upper border of the fifth lumbar spine.

Just below the crest there is a shallow furrow, termed the *iliac furrow*; it is caused by the lateral abdominal muscles, which bulge over the crest, forming a thick, oblique roll.

Surface relations of other structures.—*The lower limit of the spinal cord corresponds to the interval between the spines of the first and second lumbar vertebræ. This corresponds approximately to the level of the elbow joint when the arm is by the side. The subarachnoid space extends downwards to the horizontal level of the upper border of the third sacral spine* (fig. 1288).

As already described (p. 1083) the roots of the spinal nerves become gradually longer from the first cervical to the coccygeal, and the levels at which they are attached to the spinal cord are therefore higher than the levels at which they emerge from the intervertebral foramina. The positions of the nerve roots relative to the vertebral column are shown in fig. 1289 and in the table attached thereto, page 1452.

Fig. 1287.—A diagram showing the relation of the spinal cord to the dorsal surface of the trunk. The bones are outlined in red.

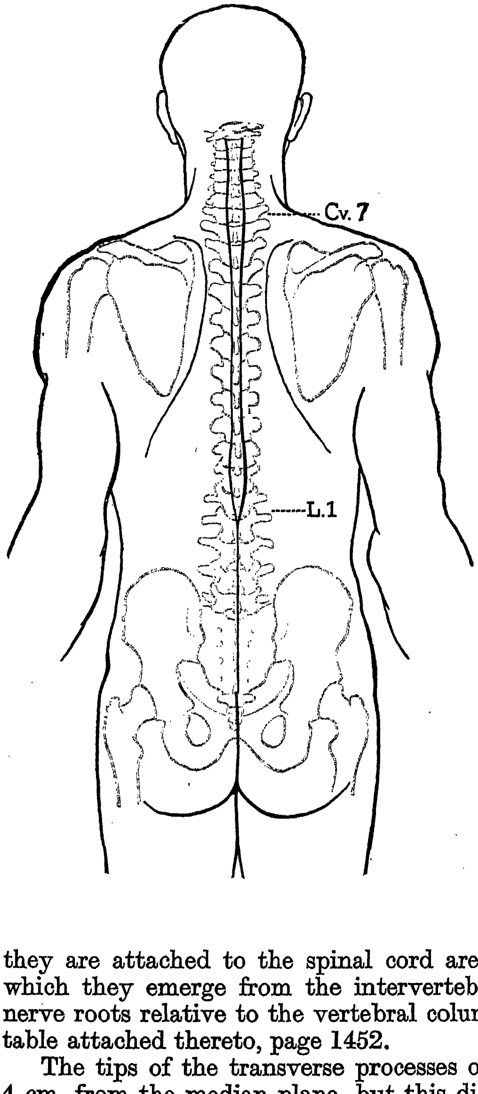
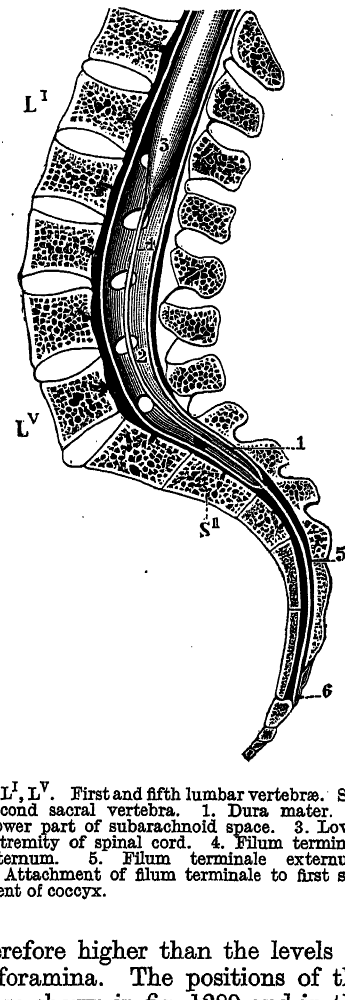


Fig. 1288.—A sagittal section through the lower part of the vertebral canal to show the lower ends of the spinal cord and subarachnoid space, and the filum terminale. (Testut.)



L I, L V. First and fifth lumbar vertebræ. S II. Second sacral vertebra. 1. Dura mater. 2. Lower part of subarachnoid space. 3. Lower extremity of spinal cord. 4. Filum terminale internum. 5. Filum terminale externum. 6. Attachment of filum terminale to first segment of coccyx.

The tips of the transverse processes of the thoracic vertebræ lie 3 cm. to 4 cm. from the median plane, but this distance diminishes from above downwards. The tip of the transverse process of the third lumbar vertebra, which is the longest lumbar transverse process, is 4·5 cm. from the median plane.

The *cervical pleura* and the *apex of the lung* reach the level of the seventh cervical spine at a distance of 2·5 cm. from the median plane.

The *lower limit of the pleural sac* extends down to a point 2 cm. lateral to the upper border of the twelfth thoracic spine and can be indicated by a line drawn downwards and laterally from this point to cut the lateral border of the sacrospinalis just where the tip of the twelfth rib emerges from under cover of the muscle. The *lower limit of the lung* is 5 cm. above the lower limit of the pleura in quiet respiration (fig. 1290).

Level of body of	No. of nerve.	Level of tip of spine of
C. 1	C. 1	..
	2	..
2	3	1 C.
3	4	2
4	5	3
5	6	4
6	7	5
..	8	6
7	T. 1	7
T. 1	2	1 T.
2	3	..
3	4	2
4	5	3
5	6	4
6	7	5
7	8	6
8	9	7
9	10	8
10	11	9
..	12	10
11	L. 1	11
..	2	..
12	3	..
..	4	12
	5	
	S. 1	..
L. 1	2	
	3	
	4	1 L.
	5	
	C. 1	
L. 2	..	..

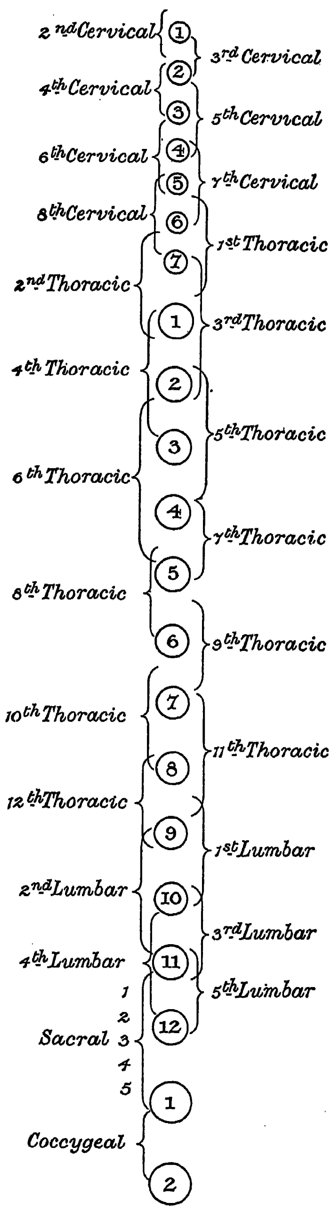
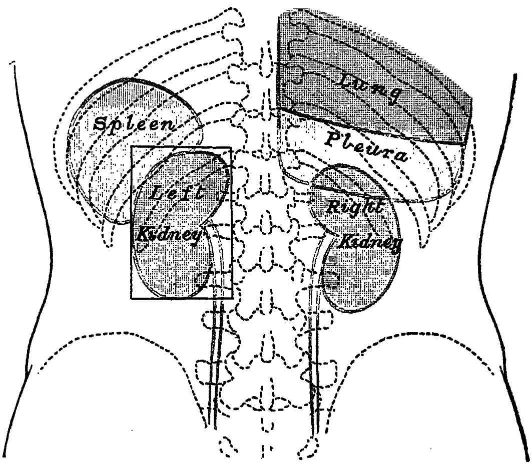


FIG. 1289.—A scheme showing the relations of the vertebral spines to the regions of attachment of the spinal nerves. (After Reid.)

The *kidneys* can be mapped out on the dorsal aspect of the trunk within Morris' parallelogram, which is included between two horizontal lines, drawn through the eleventh thoracic and the third lumbar spines, and two vertical lines, drawn 2·5 cm. and 9·5 cm. from the median plane (fig. 1290). The centre

of the hilum lies opposite the lower border of the first lumbar spine. The *ureter* corresponds to a line drawn downwards from the lower part of the hilum, 4 cm. from the median plane, to the dimple which overlies the posterior superior iliac spine. It lies, as a rule, medial to the tips of the transverse processes of the lumbar vertebræ.

FIG. 1290.—The lower limits of the lung and pleura, viewed from behind.



The lower portions of the lung and pleura are shown on the right side

The *spleen* varies so much in its size and shape that outlines drawn on the surface of the body can be only approximately accurate. For all practical purposes it may be taken as occupying an area mapped out by a line covering the middle three-fifths of the eleventh rib of the left side and a curved line which joins its two ends and extends upwards and forwards to the ninth rib (fig. 1290). On percussion over the spleen, dulness should not extend forwards beyond the midaxillary line when the organ is of normal size.

THE THORAX

Surface landmarks.—The *sternal angle* forms a ridge which can easily be felt through the skin ; traced laterally, it leads to the *second costal cartilage*, which can be identified with certainty. The sternal end of the *first costal cartilage* may be felt immediately below the medial end of the clavicle, but it is by no means a conspicuous landmark. The third and succeeding ribs (with the possible exception of the twelfth) can all be palpated, and confusion may be avoided if the ribs are identified from above downwards, starting at the second. As the cartilages of the fifth, sixth and seventh ribs approach the sternum, the intervals between them become narrower (fig. 304) and it is best, in passing downwards, to pass gradually further from the sternum. At the sternal ends of the second, third and fourth intercostal spaces the margin of the sternum can be felt indistinctly.

The *costal margin,* which is formed by the cartilages of the tenth, ninth, eighth and seventh ribs, can be seen through the skin, except in fat subjects. The two margins enclose the *infrasternal angle* (subcostal angle), where a shallow depression is visible in most cases ; this depression overlies the xiphoid process. At the apex of the angle the xiphisternal joint may be felt as a short transverse ridge.

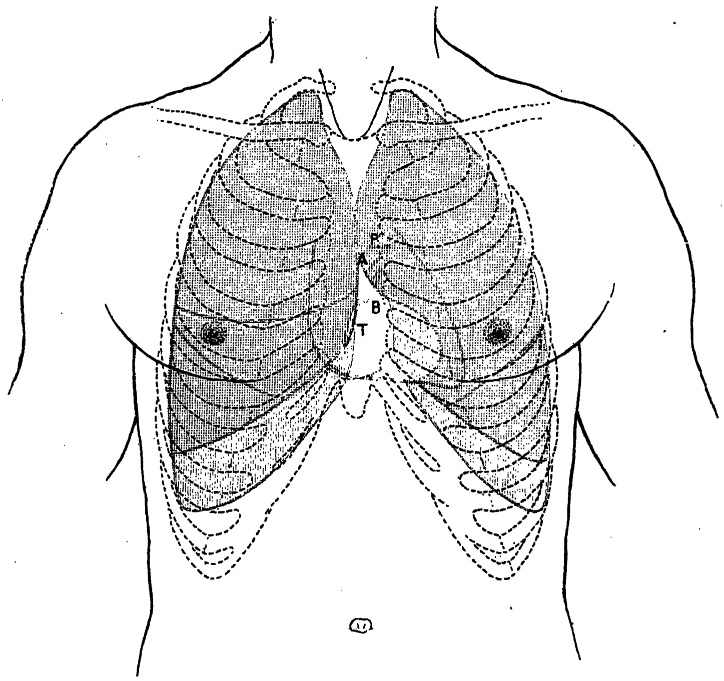
The *apex-beat* of the heart can often be seen and can always be felt a little below and a little medial to the left nipple (p. 1429). As a general rule it will be found in the fifth intercostal space about 9 cm. ($3\frac{1}{2}$ inches) from the median plane.

Surface relations of other structures.—The *internal mammary artery* can be represented by a line which begins 2 cm. above the sternal end of the clavicle

and runs downwards, 1·2 cm. from the lateral margin of the sternum or 3·5 cm. from the median plane, to the sternal end of the sixth costal cartilage.

The surface relations of the cervical pleura (p. 1449) and of the lower limit of the pleural sac dorsally (p. 1452) have already been described. The *costomediastinal lines of pleural reflection* are different on the two sides. On the right side the line commences at the sternoclavicular joint and runs downwards and medially to reach the midpoint of the sternal angle (fig. 1291); it then continues downwards, with a slight inclination to the left to reach the xiphisternal joint. On the left side, the line follows a similar course until the level of the fourth costal cartilage is reached; there it bends to the left to reach the sternal

Fig. 1291.—The front of the thorax, showing the surface relations of the bones, lungs (purple), pleuræ (blue), and heart (red outline).



A. Aortic valve. P. Pulmonary valve.
B. Mitral valve. T. Tricuspid valve.

margin, which it follows to the left extremity of the xiphisternal joint. The *costodiaphragmatic line of reflection* (fig. 1291) can be represented by a line which commences opposite the xiphisternal joint and passes downwards and backwards, gradually receding from the costal margin. In the midaxillary line it crosses the tenth rib and then ascends as it passes medially to reach the lateral border of the sacrospinalis opposite the tip of the twelfth costal cartilage (p. 1449).

The outline of the *apex of the lung* corresponds to the outline of the cervical pleura (p. 1449), and the *anterior margin of the right lung* can be regarded as identical with the costomediastinal line of pleural reflection. The *anterior margin of the left lung* corresponds also to the costomediastinal line of pleural reflection, above the level of the fourth costal cartilage. At that level it passes laterally for 3·5 cm. before curving downwards and medially to reach the sixth costal cartilage 4 cm. from the median plane (fig. 1291). The *lower border of the lung* can be represented, during quiet respiration, by a line drawn from the lower end of the anterior border to reach the eighth rib in the midaxillary line, where it lies nearly 10 cm. above the costal margin; the line is then continued medially and slightly upwards across the back to a point 2 cm. lateral to the tenth thoracic spine (fig. 1290).

The *oblique fissure* of the lung commences opposite a point 2 cm. lateral to the second thoracic spine, and can be represented by a line drawn downwards and laterally across the scapula, below and roughly parallel to the posterior border of the deltoid muscle. Attempts to continue the line uninterruptedly round to the anterior aspect of the chest are unsatisfactory. The fissure can, however, be represented on the front of the chest by a line drawn from a point, 3 cm. lateral to, and at the level of, the nipple, downwards and medially to reach the sixth costal cartilage 7·5 cm. from the median plane. When the hand is placed on the back of the head, the upper part of the oblique fissure corresponds to the vertebral border of the scapula. The *transverse fissure* of the right lung can be indicated by a line drawn from the median plane laterally along the fourth right costal cartilage. At its lateral end the transverse meets the oblique fissure, but owing to the bulk of the anterior axillary fold, attempts to carry the lines of these fissures to their meeting place in the mid-axillary line are unconvincing.

The heart.—The sternocostal surface of the heart can be projected on to the anterior chest-wall and forms an irregular, quadrangular area. The *right border* (fig. 1292) of the heart corresponds to a line drawn from the upper border of the right third costal cartilage, 1·2 cm. from the margin of the sternum, downwards to the sixth costal cartilage. This line is gently convex to the right and is at its maximum distance from the median plane—3·7 cm.—in the fourth intercostal space. It represents the lateral aspect of the right atrium. The continuation of this line in an upward direction marks the lateral border of the superior vena cava and, in a downward direction, the lateral border of the inferior vena cava.

The *lower border* of the heart can be represented by a line joining the lower end of the right border to the apex-beat (p. 1453); it passes through the xiphisternal joint, and corresponds for the most part to the lower margin of the right ventricle (p. 672). The *left border* of the heart is represented by a line drawn from the apex-beat upwards and medially to a point on the lower border of the left second costal cartilage, 1·2 cm. from the sternal margin. This line is convex upwards and to the left; with the exception of its upper part, which demarcates the left auricle, it corresponds to the left ventricle (p. 672).

It is customary to complete the quadrangular area by a line which joins the upper ends of the right and left borders, and corresponds roughly to the upper limits of the atria.

The *pulmonary orifice* (fig. 1291) lies partly behind the upper border of the left third costal cartilage and partly behind the sternum. It can be represented by a horizontal line, 2·5 cm. long. Two parallel lines, drawn from the extremities of this line upwards and slightly to the left to reach the second costal cartilage, map out the *pulmonary trunk.*

The *aortic orifice* (fig. 1291) lies below and a little to the right of the pulmonary orifice. It corresponds to a line, 2·5 cm. long, drawn from the medial end of the left third intercostal space downwards and to the right. Two parallel lines, drawn from the extremities of this line upwards and to the right as far as the right half of the sternal angle, outline the *ascending aorta.*

The *right atrioventricular,* or *tricuspid, orifice* (fig. 1291) can be represented by a line, 4 cm. long, commencing in the median plane opposite the fourth costal cartilage, and passing downwards and slightly to the right. The centre of this line should be opposite the middle of the fourth intercostal space. The *left atrioventricular,* or *mitral, orifice* lies behind the left half of the sternum opposite the fourth costal cartilage and can be represented by a line, 3 cm. long, passing downwards and to the right.

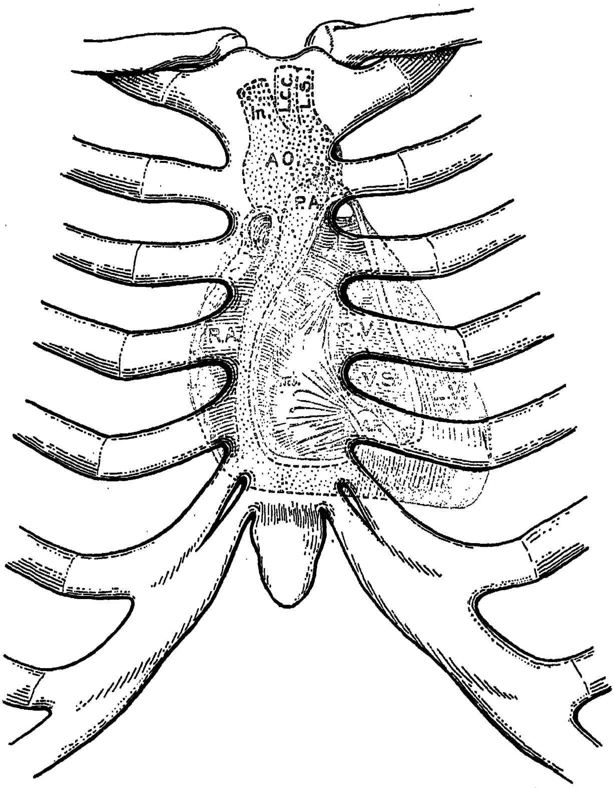
The *atrioventricular groove* can be outlined, with sufficient accuracy for all practical purposes, by joining the lower end of the line marking the tricuspid orifice to the upper end of the line marking the mitral orifice. The *anterior interventricular groove* corresponds to a line drawn downwards from the left extremity of the pulmonary orifice, parallel to the left border of the heart, to the lower border.

The *area of superficial cardiac dulness* is a roughly triangular area, bounded medially by a line drawn in the median plane from the level of the fourth costal cartilage to the xiphisternal joint; inferiorly, by a horizontal line drawn to the left for 6 cm. from the xiphisternal joint; and, superiorly, by a curved line,

convex upwards and to the left, joining the ends of the other boundaries. It corresponds to the portion of the heart which is not covered with lung.

The *arch of the aorta* (fig. 1292) lies behind the lower half of the manubrium sterni; its convex, outer border can be mapped out by a line which commences behind the right extremity of the sternal angle and arches upwards and to the left, through the centre of the manubrium, to end behind the sternal extremity of the left second costal cartilage. *Owing to its backward inclination, the arch is considerably foreshortened when projected on to the surface* (Pl. XIII, fig. 1). The *descending thoracic aorta* commences behind the sternal end of the left

FIG. 1292.—A diagram showing the relations of the opened heart to the front of the thoracic wall.



Ant. Anterior segment of tricuspid valve. AO. Aorta. A.P. Anterior papillary muscle. In. Innominate artery. L.C.C. Left common carotid artery. L.S. Left subclavian artery. L.V. Left ventricle. P.A. Pulmonary artery. R.A. Right atrium. R.V. Right ventricle. V.S. Ventricular septum.

second costal cartilage and can be mapped out as a band, 2·5 cm. broad, which runs downwards and medially to reach the median plane 2 cm. above the transpyloric plane (p. 1458).

The *innominate artery* (fig. 1292) can be represented by a broad line drawn upwards and to the right from the centre of the manubrium to the right sternoclavicular joint. The *left common carotid artery* corresponds to a broad line drawn upwards and to the left from a point a little to the left of the centre of the manubrium to the left sternoclavicular joint. The *left subclavian artery* arises immediately to the left of the origin of the preceding artery and corresponds to a line drawn upwards to the left sternoclavicular joint.

The *superior vena cava* extends from the lower border of the first to the upper border of the third costal cartilage of the right side. It is 2 cm. wide and is partly under cover of the right margin of the sternum. The *right innominate vein* is formed behind the medial end of the right clavicle and extends downwards and medially to the lower border of the right first costal cartilage close to the sternum; it should be represented by two parallel lines, 1·5 cm. apart. The *left innominate vein* commences behind the sternal end of the left clavicle

and passes downwards and to the right, behind the sternoclavicular joint and the upper half of the manubrium, to the lower end of the right innominate vein; it also should be represented by two parallel lines, 1·5 cm. apart.

The *trachea* can be mapped out by two parallel lines, 2 cm. apart, which commence immediately below the arch of the cricoid cartilage and terminate at the sternal angle, inclining very slightly to the right as they descend. From the termination of the trachea, the *right bronchus* runs downwards and to the right for 2·5 cm. to gain the hilum of the right lung opposite the sternal end of the third right costal cartilage. The *left bronchus* descends from the same point but makes a smaller angle with the trachea; it passes downwards and to the left for 5 cm. before it enters the hilum of the left lung behind the left third costal cartilage, 3·5 cm. from the median plane.

The *œsophagus* corresponds to two parallel lines, 2·5 cm. apart, which commence at the lower border of the arch of the cricoid cartilage. At first they incline to the left as they descend, but they soon curve towards the right, and a little below the sternal angle they are equidistant from the median plane. Thereafter they incline to the left again to reach the left seventh costal cartilage, where the centre of the œsophagus lies 2·5 cm. from the median plane.

The *thoracic duct* begins about 2 cm. above the transpyloric plane (*vide infra*) and very slightly to the right of the median plane. It can be represented by a line which ascends in the median plane to the sternal angle and then inclines to the left, until, about 2·5 cm. above the clavicle, it lies 2 cm. from the median plane. Finally, it passes laterally for 1·2 cm. and then turns downwards to end behind the clavicle.

In the child the *thymus* lies behind the manubrium and the upper half of the body of the sternum, and it may project for a short distance into the neck.

THE ABDOMEN

Surface landmarks.—The *linea alba* (fig. 1293) can be seen as a linear depression in the median plane. Below the umbilicus it is visible only in young, muscular subjects, but between the umbilicus and the xiphoid process it can usually be recognised without much difficulty. At its lower end the linea alba terminates at the upper border of the *pubic symphysis*, which can be felt indistinctly. From this point the *pubic crest* can be traced laterally to the *pubic tubercle*. The *linea semilunaris* (fig. 1293) is a curved groove which can be seen marking the position of the lateral border of the rectus abdominis; it crosses the costal margin at or near the tip of the ninth costal cartilage and terminates below at the pubic tubercle.

The interval between the linea alba and the linea semilunaris is occupied by the *rectus abdominis*. In lean and muscular subjects transverse depressions may be seen crossing its surface, one at the umbilicus and one midway between the umbilicus and the xiphoid process; they indicate the position of the tendinous intersections which cross the surface of the muscle (p. 568).

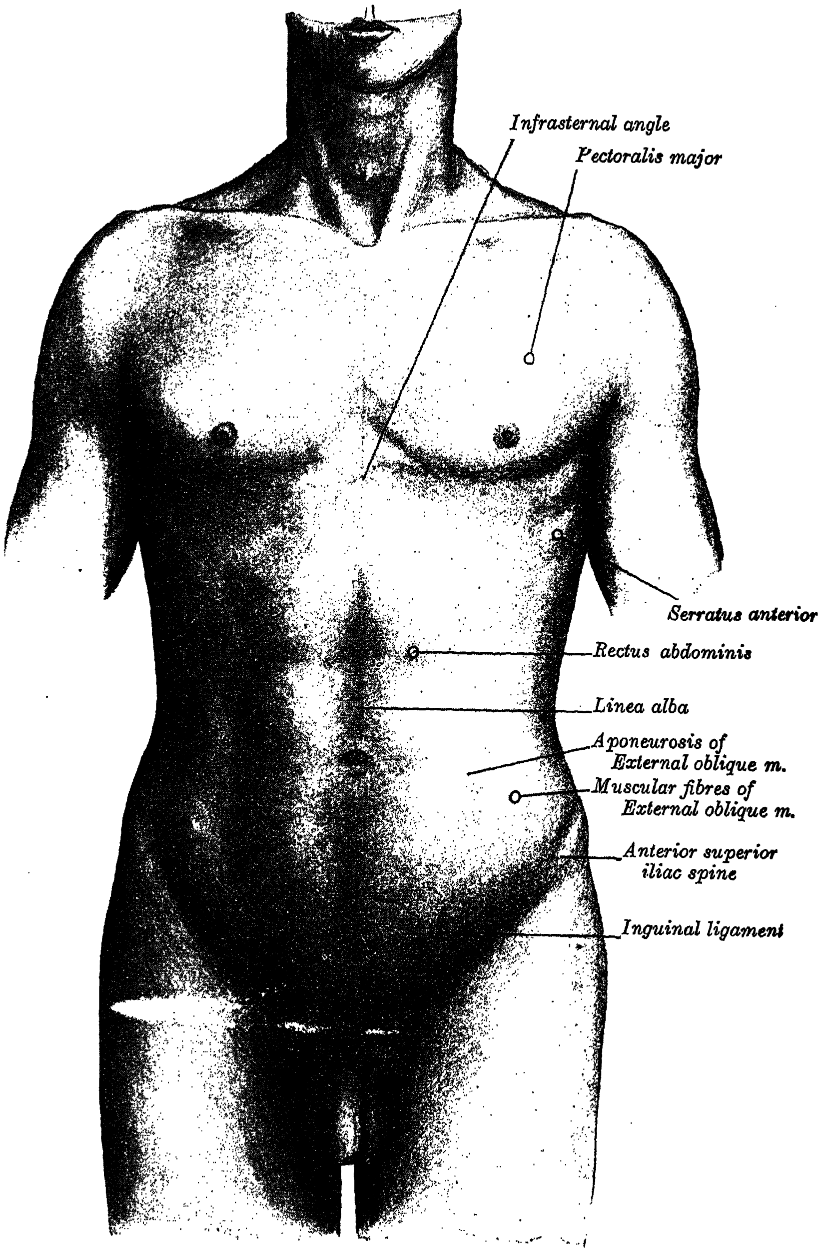
The *umbilicus* forms an important landmark. In the young adult it lies on a level with the intervertebral disc between the third and fourth lumbar vertebræ, but as age advances, it tends to sink to a somewhat lower level.

The *spermatic cord* can be grasped between the finger and thumb at the neck of the scrotum, and the *vas deferens* can be identified in its substance owing to its characteristic cordlike consistence. If the skin of the scrotum is invaginated in an upward and lateral direction the spermatic cord can be followed up to the superficial inguinal ring. If the examining finger is then directed backwards the crura of the ring can be recognised.

The costal margin and infrasternal (subcostal) angle (p. 1453), the iliac crest (p. 1449) and the inguinal ligament (p. 1465) are dealt with in other sections.

Certain artificial landmarks are helpful in facilitating the reference of abdominal viscera to the surface of the abdomen. Of these, the most useful is the *transpyloric plane* (fig. 1294), which is drawn round the body, midway between

FIG. 1293.—The surface anatomy of the front of the thorax and abdomen.



the suprasternal notch and the pubic symphysis. The right and left lateral, the subcostal and the transtubercular planes are described on p. 1303.

Surface landmarks of other structures in the abdominal wall.—The *upper limit of the rectus abdominis* can be represented by a horizontal line drawn from the xiphisternal joint to the fifth costal cartilage. A curved line, convex upwards, drawn across the muscle midway between the umbilicus and the pubic

symphysis, indicates the position of the *arcuate line* (linea semicircularis) (p. 569).

The line along which the fleshy fibres of the external oblique muscle merge into its aponeurosis is parallel with and 0·5 cm. lateral to the linea semilunaris. Just above the level of the anterior superior iliac spine, it bends laterally towards that bony point (fig. 595). It should be noted carefully that no fleshy fibres of the external oblique muscle descend below the line joining the anterior superior spine of the ilium to the umbilicus. The line along which the fleshy fibres of the internal oblique muscle merge into its aponeurosis begins near the tip of the tenth costal cartilage (fig. 599) and runs downwards and slightly medially to a point about 2·5 cm. vertically above the medial end of the inguinal ligament. The line along which the fleshy fibres of the transversus abdominis merge into its aponeurosis is curved, with its convexity laterally. It begins just medial to the costal margin below the xiphisternal joint and runs downwards and laterally, crossing the linea semilunaris at the level of the tip of the tenth costal cartilage. Opposite the umbilicus it lies 1·5 cm. to 2 cm. lateral to the linea semilunaris, and it then curves downwards and medially to a point 2·5 cm. vertically above the medial end of the inguinal ligament.

The centre of the *deep inguinal ring* lies 1 cm. above the midpoint of the line joining the anterior superior iliac spine to the pubic tubercle; the centre of the *superficial inguinal ring* lies 1 cm. above and the same distance lateral to the pubic tubercle. The line of the *inguinal canal*, which is about 3·7 cm. long, can be obtained by joining these two points (fig. 1297).

The *inferior epigastric artery* (fig. 1297) can be represented by a line drawn from the midpoint of the line joining the anterior superior iliac spine to the pubic symphysis upwards towards the umbilicus.

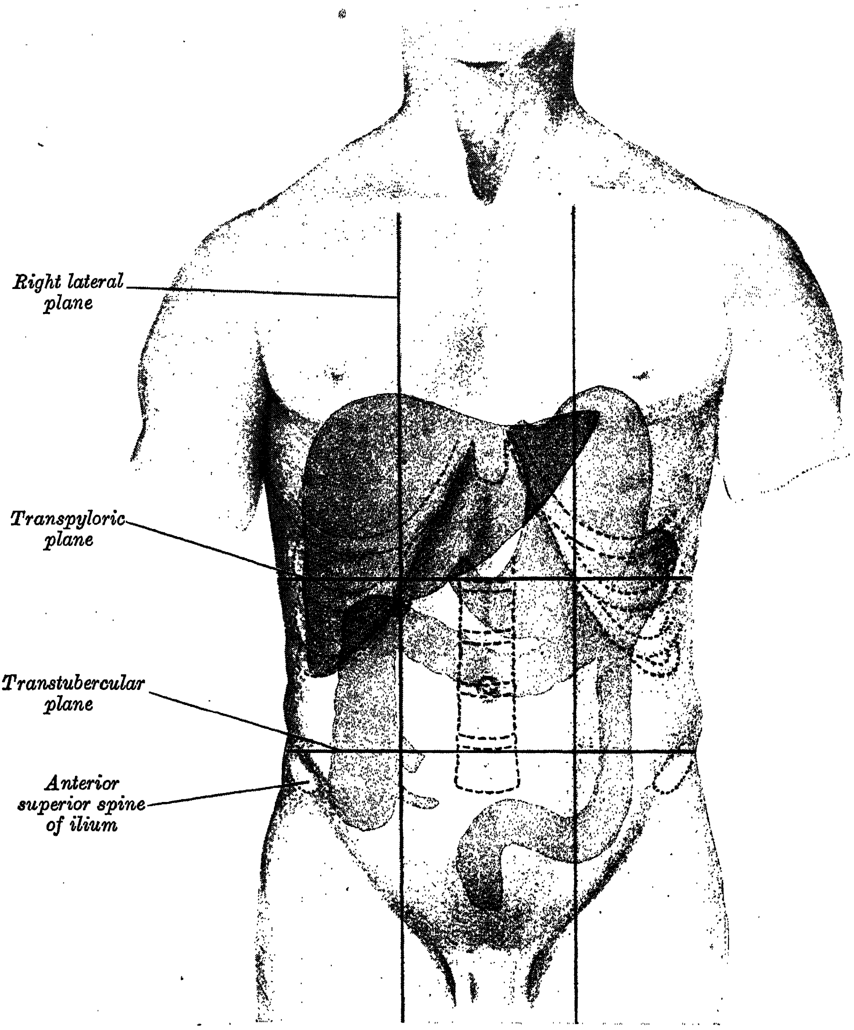
The *seventh* and *eighth intercostal nerves* (fig. 980) turn upwards as they cross the costal margin. The seventh follows the margin closely, but the eighth corresponds to a line drawn upwards and medially from the tip of the ninth costal cartilage, at a distance of 0·5 cm. medial to the costal margin. The *lower intercostal nerves* continue forwards in the lines of the corresponding intercostal spaces.

Surface relations of structures within the abdominal cavity.*—The *stomach* lies in the upper left quadrant of the abdominal cavity and part of its outline overlies the lower ribs and cartilages of the left side. The *cardiac orifice* (fig. 1294) lies behind the seventh costal cartilage 2·5 cm. to the left of the median plane and can be represented by two short, parallel lines, 2 cm. apart, inclining downwards and to the left. It is placed 10 cm. from the surface of the abdominal wall and is 40 cm. (16 inches) from the incisor teeth. The *pylorus* (fig. 1294) lies on the transpyloric plane, 1·2 cm. to the right of the median plane, and can be outlined by means of two short, parallel lines, 2 cm. apart, directed upwards and to the right. The *lesser curvature* of the stomach can be mapped out by joining the right margin of the cardiac orifice to the upper (or left) margin of the pylorus by means of a curved J-shaped line, which descends at its lowest point below the transpyloric plane. The *fundus* of the stomach corresponds to a line, convex upwards, drawn from the left margin of the cardiac orifice and reaching its summit in the left fifth intercostal space just below the nipple. A curved line, convex to the left and downwards, drawn from the fundus to the lower, or right, margin of the pylorus, outlines the *greater curvature*. It cuts the left costal margin between the tips of the ninth and tenth costal cartilages and extends downwards to the subcostal plane.

* The relations detailed in this section refer to the body in the recumbent position, but it must be remembered that posture is not the only factor which affects the position of the viscera. Respiratory movements and the condition of the hollow organs as regards contents exercise an important influence. In addition there is a wide range of individual variation, associated, in part at least, with the type of chest, and there is an appreciable range of variation in the same individual examined at different times, and independent of the factors already noted. It follows, therefore, that *in the absence of such accessories as X-ray photographs attempts to outline the viscera, especially the hollow viscera, on the surface of the living model may prove very unsatisfactory*, and that the markings given in this section, as well as the outlines shown in the accompanying figures, must be regarded as variable within very wide limits.

The *duodenum* * (fig. 1296) lies entirely above the umbilicus, and is about 2·5 cm. wide. Its *first part* passes upwards and to the right for 2·5 cm. from the pylorus (Pl. XV, fig. 1), and from its upper end the *second part* runs downwards for 7·5 cm., lying medial to the right lateral plane. The *third part* passes from the lower end of the second part transversely to the left, above the umbilicus, and after crossing the median plane, turns upwards into the *fourth part.* The latter ends at the *duodenojejunal flexure,* which is situated 2·5 cm. to the left of the median plane and 1 cm. below the transpyloric plane.

FIG. 1294.—The surface relations of the stomach, liver and large intestine.



The *pancreas* (fig. 1296) stretches obliquely across the posterior abdominal wall, lying more to the left than to the right of the median plane. Its *head* lies within the curve formed by the first, second and third parts of the duodenum and its *neck* passes upwards and to the left behind the pylorus. Its body can be represented by two parallel lines, 3 cm. apart, drawn upwards and to the left for 10 cm. to 12 cm. from the neck.

The *liver* (fig. 1296), which occupies the upper right quadrant of the abdominal cavity, is roughly triangular in shape when projected on to the anterior aspect of the trunk. Its *upper border* corresponds to a line drawn through the xiphisternal joint and ascending to the right to a point a little below the right

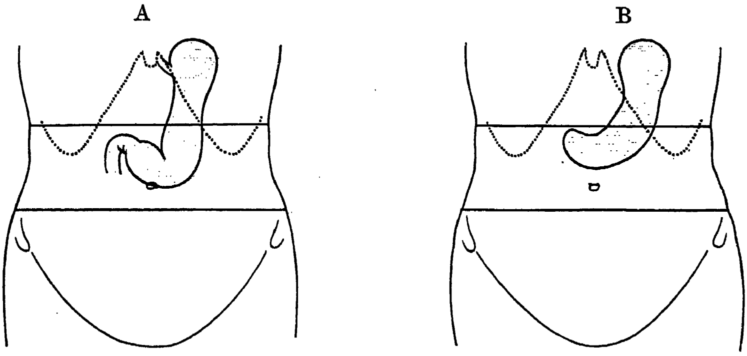
* See footnote on p. 1459.

nipple, and ascending less sharply to the left to a point a little below and medial to the left nipple. Its *right border* corresponds to a curved line, convex to the right, drawn from a point a little below the right nipple to a point 1 cm. below the right costal margin at the tip of the tenth costal cartilage. Its *lower border* can be represented by joining the lower end of its right border to the left end of its upper border ; this line should cross the median plane at the transpyloric plane, should show a slight concavity opposite the right linea semilunaris and may be slightly concave to the left in its upper part. The fundus of the *gall bladder* (fig. 1294) can be outlined on the surface in the angle between the right costal margin and linea semilunaris ; it occupies the notch indicated above on the lower border of the liver. The *bile duct* corresponds to a line which begins 5 cm. above the transpyloric plane and 2 cm. to the right of the median plane, and runs downwards for 7·5 cm., inclining to the right in its lower half.

The area which is bounded on the right by the lower margin of the left lobe of the liver, above by the left lung, on the left by the spleen and below by the costal margin, overlies the stomach and is often termed *Traube's space*.

The *cæcum* * (fig. 1294) occupies the triangular area bounded by the right lateral plane, the transtubercular plane and the fold of the groin (p. 1465). The

FIG. 1295.—Skiagrams of a half-filled stomach, showing the influence of posture. (After A. F. Hurst.)



A. With the patient in the erect posture. B. With the patient lying down.

ileocolic orifice lies opposite the point of intersection of the transtubercular and the right lateral planes, and 2 cm. below this point the *vermiform appendix* opens into the cæcum.† (Pl. XVII.)

The *ascending colon* * (fig. 1294), which is usually about 5 cm. wide, lies immediately to the right of the right lateral plane and ascends from the transtubercular plane to midway between the subcostal and the transpyloric planes.

The *transverse colon* * (fig 1294) can be represented by a band, 5 cm. wide, drawn from the upper end of the ascending colon downwards and medially to the umbilicus and then upwards and laterally to cross the transpyloric plane to the left side of the left lateral plane.

The *descending colon* * (fig. 1294) is usually contracted and is little more than 2 cm. broad ; it can be represented by a band which commences above the transpyloric plane and descends, just lateral to the left lateral plane, as far as the fold of the groin (p. 1465).

The *kidney* * lies with its upper and lateral part under cover of the costal margin, and its long axis is directed downwards and laterally, so that its upper pole is nearer to the median plane than its lower pole. The viscus measures 11 cm. long and 6·5 cm. wide, but, owing to foreshortening its width is reduced

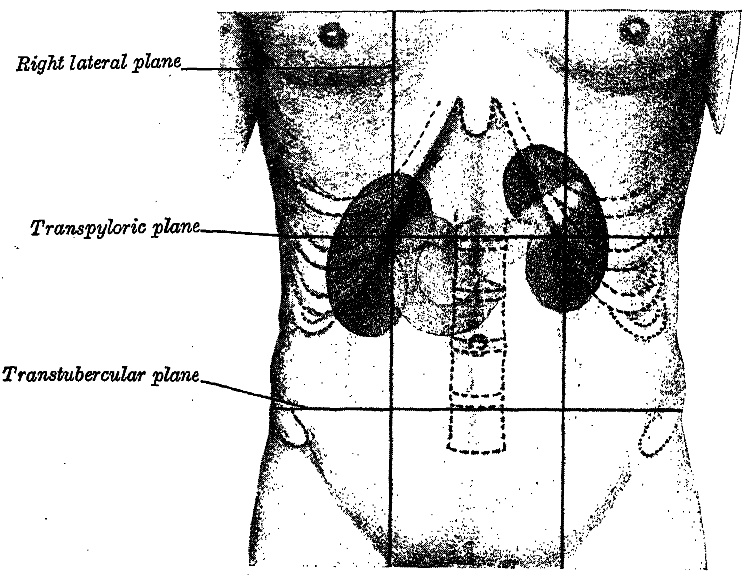
* See footnote on p. 1459.

† McBurney marked the base of the vermiform appendix opposite the junction of the lower and middle thirds of the line joining the anterior superior iliac spine to the umbilicus.

to 5 cm. when it is projected on to the anterior surface of the trunk. The centre of the hilum lies 5 cm. from the median plane ; that of the right kidney lies a little below the transpyloric plane, that of the left kidney a little above it. With the aid of these measurements the kidney can be mapped out on the anterior surface of the abdomen with sufficient accuracy for all practical purposes (fig. 1296). The outlines of the kidneys on the posterior surface of the body are described on p. 1452.

The *pelvis of the ureter* lies opposite the hilum of the kidney and extends downwards to a point 5 cm. below the transpyloric plane and the same distance from the median plane (Pl. II, fig. 2). The *ureter* can be represented by a line drawn downwards and slightly medially from the lower end of its pelvis towards the pubic tubercle ; as it enters the pelvis it crosses the termination of the common iliac artery (*vide infra*).

FIG. 1296.—The surface relations of the duodenum, pancreas and kidneys.



The *suprarenal glands* can be mapped out on the surface immediately medial to the costal margin. The left gland, which measures 4·5 cm. long and 2 cm. wide, is closely applied to the medial border of the left kidney above the hilum ; the right gland, which is triangular in outline and measures 3 cm. long and 3 cm. wide, is placed at the upper pole of the right kidney.

The *abdominal aorta* (fig. 1297) commences in the median plane 2·5 cm. above the transpyloric plane. As it descends it inclines slightly to the left and it divides into its terminal branches opposite a point 1·2 cm. below the umbilicus and the same distance from the median plane. It can be represented by two parallel lines, about 2 cm. apart.

The *common iliac artery* corresponds to the upper third of a broad line drawn from the lower end of the aorta, with a slight convexity to the lateral side, to the midpoint between the anterior superior iliac spine and the pubic symphysis. The *external iliac artery* corresponds to the lower two-thirds of the same line.

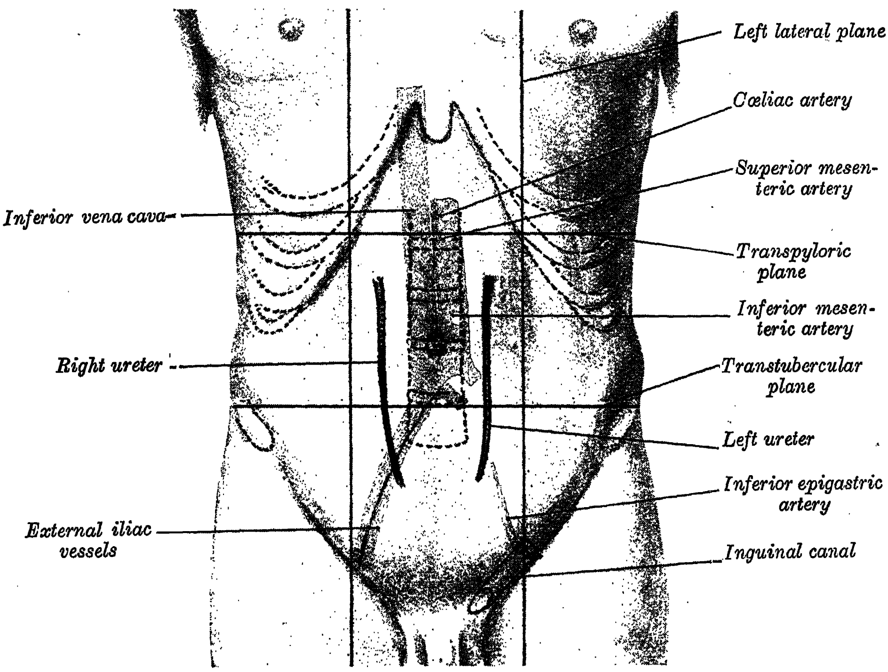
The *cœliac artery* (fig. 1297) arises opposite the commencement of the abdominal aorta. The *left gastric artery* corresponds to a line drawn from the cœliac artery upwards and to the left, in the direction of the cardiac orifice of the stomach (p. 1459). The *splenic artery* can be represented by a wavy line drawn to the left and slightly upwards for about 10 cm. from the cœliac artery. The *hepatic artery* can be marked out by a line drawn to the right and downwards from the cœliac artery for 2·5 cm. and then vertically upwards for 2 cm. to 3 cm.

The *superior mesenteric artery* (fig. 1297) begins in the median plane at, or just above, the transpyloric plane. Its course can be indicated by a line, gently convex to the left, drawn from this point to the intersection of the transtubercular and right lateral planes. The line of the artery corresponds in a general way to the line of the *root of the mesentery*, which, however, extends upwards to the duodenojejunal flexure (p. 1460).

The *renal artery* arises from the lateral aspect of the aorta, 1·5 cm. below the transpyloric plane and corresponds to a broad line drawn laterally for 4 cm. In the case of the left artery the line should incline upwards across the transpyloric plane.

The *inferior mesenteric artery* can be represented by a line which commences 2·5 cm. above the umbilicus and 1·2 cm. to the left of the median

FIG. 1297.—The surface relations of the aorta, inferior vena cava, ureters and inguinal canal.



plane, and runs downwards and slightly to the left to a point 4 cm. below the umbilicus.

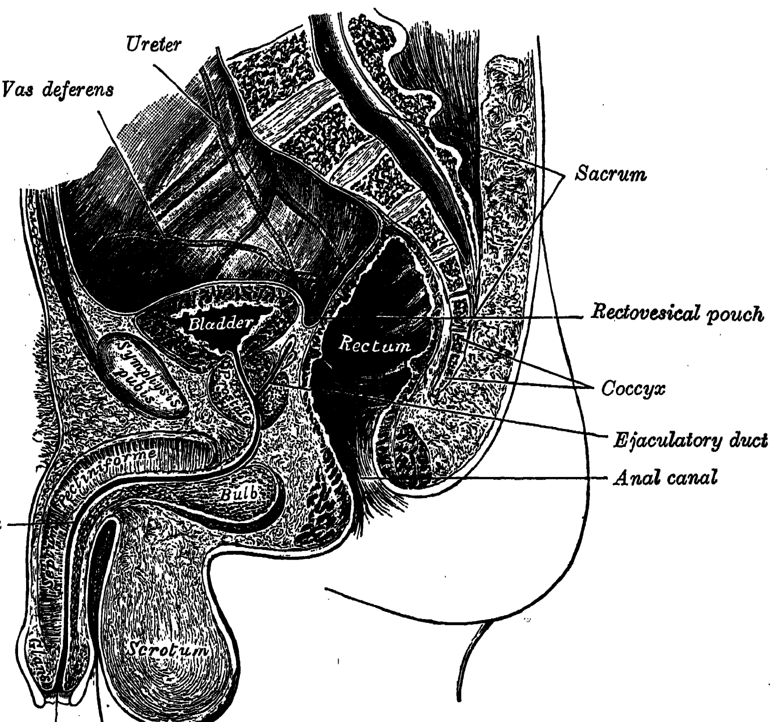
The *inferior vena cava* (fig. 1297) begins on, or just below, the transtubercular plane and its centre lies 2·5 cm. from the median plane. It can be represented by two vertical lines, 2·5 cm. apart, drawn upwards from this point to the sternal end of the right sixth costal cartilage (p. 1455). A line, drawn downwards and laterally from the lower end of the inferior vena cava to a point 1 cm. medial to the midpoint of the line joining the pubic symphysis to the anterior superior iliac spine, outlines the *common* and the *external iliac veins*. This line is slightly convex to the lateral side, the curvature being greater on the left side.

The *portal vein*, which is 1·5 cm. to 2 cm. wide, corresponds to a broad band drawn upwards and to the right for 5 cm. from a point on the transpyloric plane 1·2 cm. to the right of the median plane.

The Perineum

The *anal orifice* lies in the median plane of the posterior part of the perineum about 4 cm. in front of the *tip of the coccyx,* which can be felt at the bottom of the natal cleft. The skin around the anus is thrown into a series of converging folds, which are continued upwards into the lower part of the anal canal. The skin covering the scrotum is rough and corrugated, but over the penis it is smooth and thin. A median ridge, which indicates the position of the scrotal raphe, extends forwards from the anus, over the scrotum to the penis. The *testes* can be palpated through the skin of the scrotum, and along the posterior border of each the curved *epididymis* can be identified. The spermatic cord and the vas deferens have already been described (p. 1457).

Fig. 1298.—A median sagittal section through the male pelvis.



The external genital organs in the female have been described on pp. 1405 to 1407.

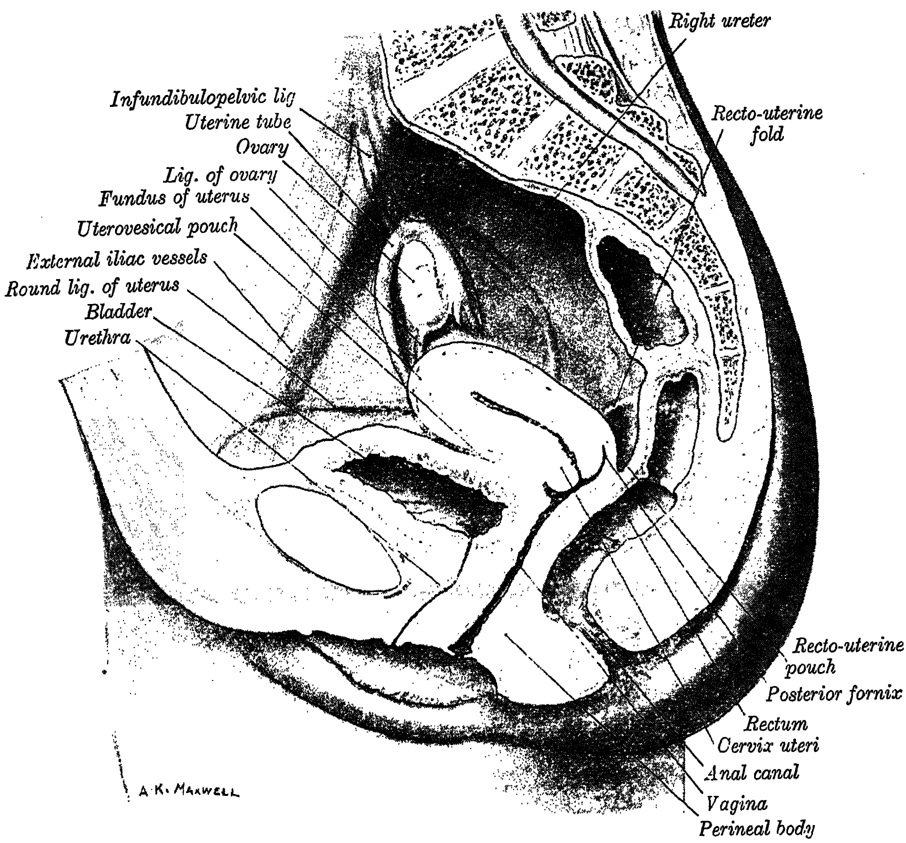
The whole outline of the *pubic arch* can be felt through the skin, from the pubic symphysis to the ischial tuberosity. Posteriorly, on each side, the edge of the *sacrotuberous ligament* can be felt on deep pressure under the medial part of the lower border of the gluteus maximus (p. 1470).

The *rectum* and *anal canal.*—A finger inserted through the anal orifice enters the anal canal, which passes upwards and forwards for about 2·5 cm. and then bends sharply backwards into the rectum. The finger is first grasped by the external and then by the internal sphincter, and at the upper end of the canal it encounters the resistance of the puborectalis; beyond this it may reach the lowest of the horizontal rectal folds. In front (fig. 1298) the *bulb of the penis* and the *membranous part of the urethra* are first identified and then, about 4 cm. above the anal orifice, the *prostate* can be felt; beyond this the *seminal vesicles,* if enlarged, and the base of the bladder may be recognised. Posteriorly the

pelvic surfaces of the lower part of the sacrum and the coccyx may be palpated.

The *vagina.*—A finger inserted into the vagina comes into contact above with the vaginal portion of the *cervix uteri*, and the lips of the *external os uteri* can be palpated. In front of the cervix, the finger passes into the anterior vaginal *fornix*, through which the base of the bladder may be examined. Behind the cervix, the finger passes into the posterior vaginal fornix, through which the contents of the recto-uterine pouch can be felt (fig. 1299). If the opposite

FIG. 1299.—A median sagittal section through the female pelvis.



hand is placed on the lower part of the abdominal wall and firm pressure exercised, the whole of the cervix and body of the uterus can be examined between the two hands, and the experienced observer can determine the condition of the ovaries and the uterine tubes.

A line drawn transversely in front of the ischial tuberosities passes through the *perineal body* ; it is situated 2·5 cm. in front of the anus, or about midway between the anus and the neck of the scrotum, in the male (midway between the anus and the vaginal orifice in the female).

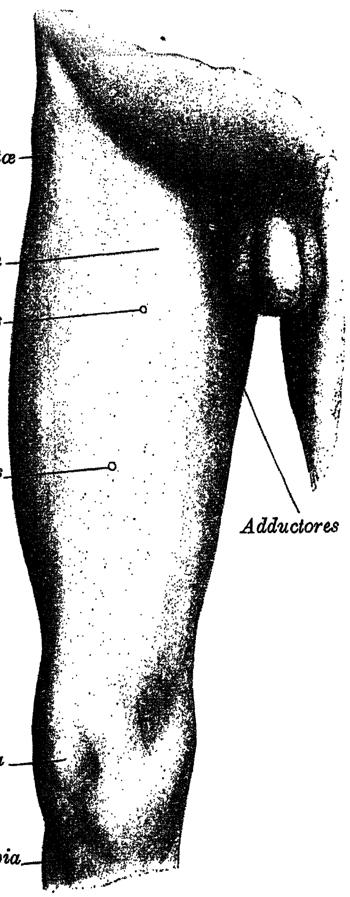
THE LOWER LIMB

The Front of the Thigh

Surface landmarks.—An oblique skin crease, which is termed the *fold of the groin* (fig. 1300), marks the junction of the front of the thigh with the anterior abdominal wall. It corresponds fairly accurately to the *inguinal ligament.* The *anterior superior spine of the ilium*, which lies at the lateral end of the fold, can always be palpated, but, on account of the normal tilt of the pelvis, the small surface elevation often visible in this situation is produced, not by the

spine, but by the adjoining part of the crest. At its medial end the fold reaches the pubic tubercle (p. 1457). Just below the midpoint of the line joining the anterior superior iliac spine to the pubic symphysis, the pulsation of the femoral artery can be felt, and in this situation the vessel can be compressed against the superior ramus of the pubis. The shallow depression which lies immediately below the fold of the groin corresponds to the *femoral triangle* (fig. 1300). It is bounded on the lateral side by the straplike *sartorius muscle*, which can be both seen and felt in the living subject, especially when the thigh is flexed against gravity and is, at the same time, slightly abducted and rotated laterally. The muscle can be traced downwards and medially from the anterior superior spine of the ilium across the front of the limb to, approximately, half-way down the medial side of the thigh (fig. 1300). In the lower part of its extent it passes vertically downwards across the medial condyle of the femur to reach its insertion. The bulky, fleshy mass at the upper part of the medial side of the thigh is formed by the *adductor group of muscles*. At its upper and medial end, the tendon of origin of the *adductor longus* can be identified immediately below the pubis.

FIG. 1300.—The front and medial surface of the right thigh.



When the thigh is flexed against gravity and the knee is extended, an angular depression becomes apparent immediately below the anterior superior iliac spine. It is bounded medially by the sartorius and laterally by the *tensor fasciæ latæ*, which forms a firm rounded prominence. This depression overlies the straight head of origin of the *rectus femoris* and the *anterior inferior iliac spine*, but neither of these structures can be palpated satisfactorily. The forward convexity of the front of the thigh is caused by the curvature of the femur, covered with the vastus intermedius and the rectus femoris. The fleshy bulge which lies medial to the upper half of the patella is produced by the lower fibres of the *vastus medialis*.

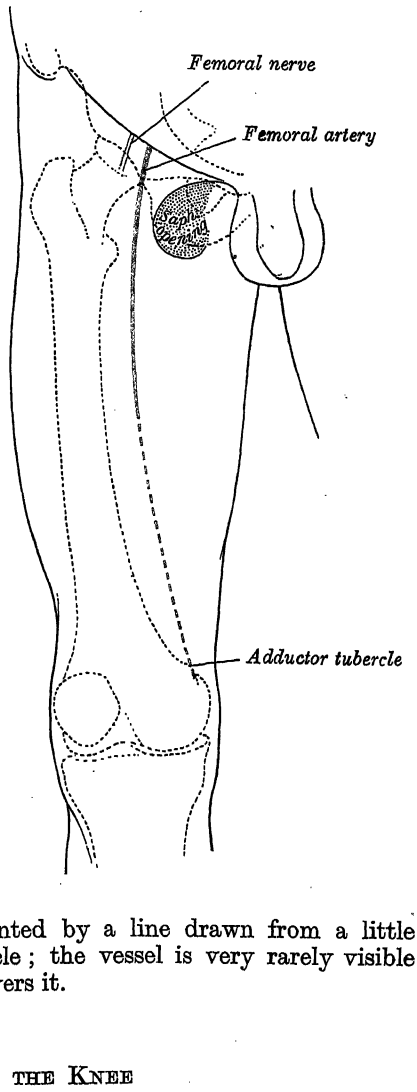
The flattened appearance of the lateral aspect of the thigh is caused by the *iliotibial tract*, which stands out as a strong, visible ridge on the antero-lateral aspect of the knee, when the leg is extended against gravity. This ridge forms the lateral boundary of the depression which lies above and lateral to the patella and is limited above by the lower fibres of the *vastus lateralis*.

The **adductor tubercle** (fig. 1301) on the medial condyle of the femur can be felt in the lower part of the thigh. It is the highest point on the medial condyle and can be identified most satisfactorily when it is approached from above. If the hand (fingers pointing downwards) is placed flat on the medial side of the thigh and carried downwards to the knee, the tip of the middle finger comes into contact with the adductor tubercle. The cord-like tendon of the *adductor*

magnus can be recognised on deep pressure immediately above the tubercle and can be traced downwards to its insertion into the bone.

Surface relations of other structures.—The *femoral artery* enters the thigh at the fold of the groin, at a point midway between the anterior superior iliac spine and the pubic symphysis. It can be represented by the upper two-thirds of a line joining that point to the adductor tubercle (fig. 1301) when the flexed thigh is abducted slightly and rotated laterally. The proximal third of this line lies in the depression corresponding to the femoral triangle and its middle third lies on the surface of the sartorius muscle. It must be remembered that, although the femoral artery lies in front of the head of the femur as it leaves the pelvis, it lies at some distance to the medial side of the shaft until it reaches the lower end of the subsartorial (adductor) canal. The *femoral vein* lies close to the medial side of the artery in the upper part of the femoral triangle, but in most of its course it lies behind the artery, inclining to its lateral side below. The *femoral nerve* enters the thigh 1·2 cm. to the lateral side of the femoral artery and can be represented by a vertical line in this situation, not more than 2·5 cm. long.

Fig. 1301.—The front of the right thigh, showing the surface markings for the bones, the femoral artery, and the femoral nerve.



The *hip-joint* lies 1·2 cm. vertically below the middle third of the inguinal ligament (Pl. VIII), which is approximately parallel to the rim of the acetabulum (fig. 1301). When the joint is extended, a part of the anterior aspect of the head of the femur lies immediately below the acetabular rim and is crossed by the femoral vessels.

The centre of the *saphenous opening* (fossa ovalis) lies nearly 4 cm. below and lateral to the pubic tubercle, and the *long saphenous vein* can be represented by a line drawn from a little below this point to the adductor tubercle; the vessel is very rarely visible in the thigh on account of the fat that covers it.

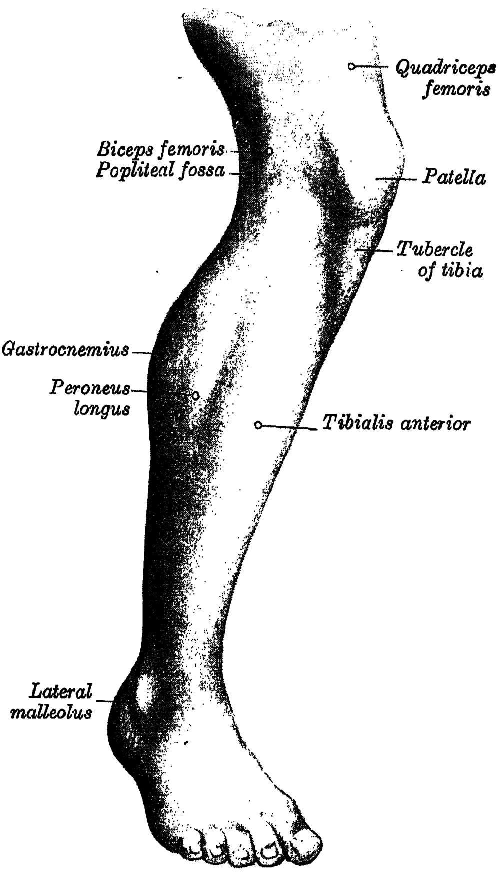
The Region of the Knee

Surface landmarks.—The *patella* can be identified readily, and, when the quadriceps is relaxed, can be tilted and moved on the lower end of the femur. Its lower limit lies more than 1 cm. above the line of the knee-joint (Pl. IX). The *ligamentum patellæ* can be traced downwards from the apex of the patella to the *tibial tubercle* (fig. 1302), and its edges can be gripped between the finger and thumb when the knee is partly extended against gravity. When the knee is flexed passively, the medial surface of the *medial condyle* and the lateral surface of the *lateral condyle of the femur* can be palpated, and portions of the femoral articular surface can be examined on each side of the lower part of the patella. When the knee is extended passively, the *sartorius* forms a slight elevation over the posterior part of the medial condyle. The *tibial condyles* form visible and palpable landmarks at the sides of the ligamentum

patellæ; the lateral condyle is the more prominent. When the knee is flexed passively the anterior margins of the tibial condyles can be felt readily, and each forms the lower boundary of a depression at the side of the patellar ligament.

The large and deep depression which can be seen at the back of the knee when the joint is actively flexed against resistance corresponds to the *popliteal fossa*. It is bounded on the lateral side by the prominent tendon of the *biceps femoris*, which can be traced downwards to the *head of the fibula* (fig. 1303). This bony point forms a slight surface elevation on the upper part of the postero-lateral aspect of the leg and lies vertically below the *posterior* part of the lateral condyle of the femur, *not less than 1 cm. below the level of the knee-joint*. The *lateral popliteal* (common peroneal) *nerve* (fig. 1303) runs downwards and laterally across the back of the head of the fibula and then curves forwards round the neck of the bone. In both situations it can be rolled against the bone, but at the neck of the fibula it is placed deep to the peroneus longus and cannot be felt so distinctly. Three tendons can be felt on the medial side of the popliteal fossa. The *semitendinosus* is the most lateral, and the *gracilis* the most medial. These two tendons stand out sharply and can be seen when the knee is flexed against resistance and the limb is adducted actively. The third tendon is the *semimembranosus*; it is more deeply situated and can be felt in the interval between the other two. In addition, it is much thicker than the others and broadens rapidly as it is traced upwards.

FIG. 1302.—The lateral surface of the right leg.



When the knee is flexed passively, the pulsation of the *popliteal artery* can be felt on deep pressure over the middle line of the popliteal fossa.

Surface relations of other structures.—The *popliteal artery* (fig. 1303) can be represented by a line which begins at the junction of the middle and lower thirds of the thigh, 2·5 cm. medial to the middle line of the back of the limb, and runs downwards and laterally to reach the middle line at the level of the knee-joint. It then descends vertically to the level of the tibial tubercle. The *medial popliteal* (tibial) *nerve* corresponds to a line which commences at the upper angle of the popliteal fossa and runs downwards in the middle line. At first lateral to the popliteal artery, the nerve gradually crosses the vessel to gain its medial side. The *lateral popliteal nerve* (fig. 1305) can be indicated by a line drawn from the upper angle of the popliteal fossa, along the medial side of the tendon of the biceps femoris to the back of the head of the fibula; it is then curved downwards and forwards round the neck of the bone.

The line of the *knee-joint* corresponds to the upper margins of the tibial condyles and can be represented by a line drawn round the limb at this level. In the angles between this line and the edges of the ligamentum patellæ the an-

terior horns of the semilunar cartilages can be indicated. The *suprapatellar bursa* extends upwards for at least 6 cm. above the patella.

The Gluteal Region and the Back of the Thigh

Surface landmarks.—The bulky prominence of the buttock is caused by three factors: (1) the forward tilt of the pelvis, which throws the ischium backwards; (2) the size of the gluteus maximus; and (3) the large amount of subcutaneous fat. The horizontal *gluteal fold* (fig. 1304) marks the upper limit of the back of the thigh; it does not correspond to the lower border of the gluteus maximus but is caused by fibrous connexions between the skin and the deep fascia. The *natal cleft*, which separates the buttocks inferiorly, commences above at the third or fourth sacral spine.

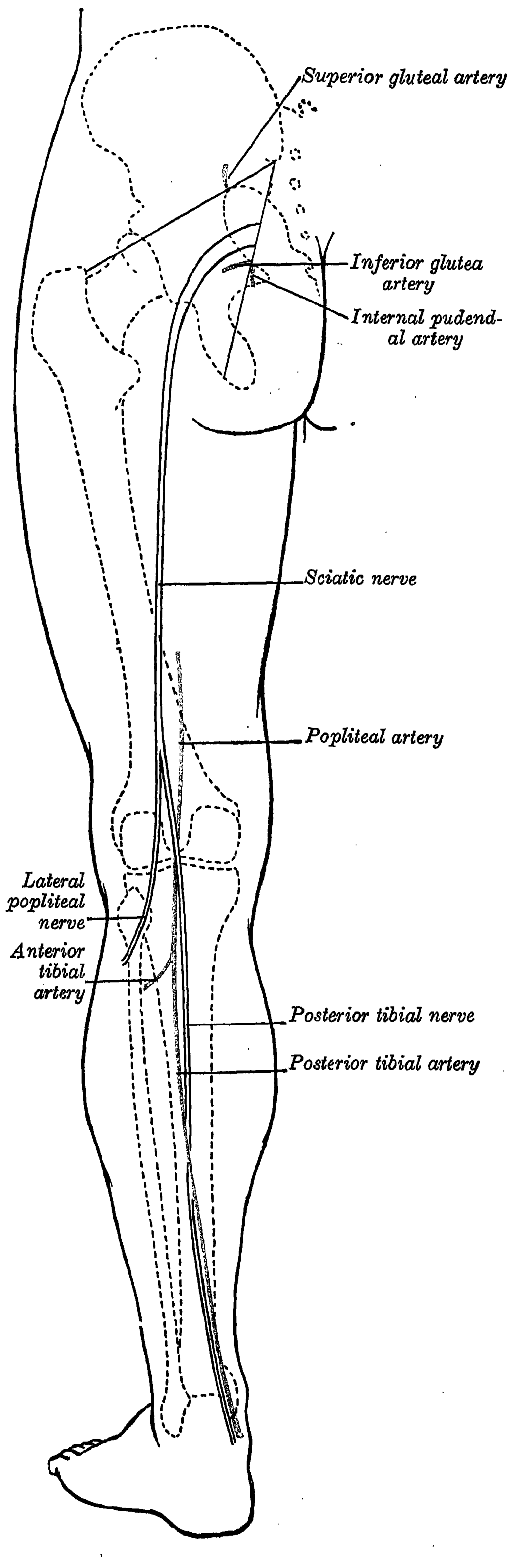
The *iliac crest*, which forms the upper limit of the buttock, has already been described (p. 1449).

The *greater trochanter* of the femur lies a hand's breadth below the tubercle of the iliac crest. When the body is in the upright posture, the lateral surface and posterior margin of the trochanter can be felt through the skin. Above and behind it there is a shallow depression, which overlies the aponeurosis of the gluteus maximus.

The *tuberosity of the ischium* is covered with the gluteus maximus when the hip-joint is extended, but it can be identified without difficulty when the joint is flexed. It is placed about 5 cm. from the median plane and about the same distance above the gluteal fold (fig. 1303).

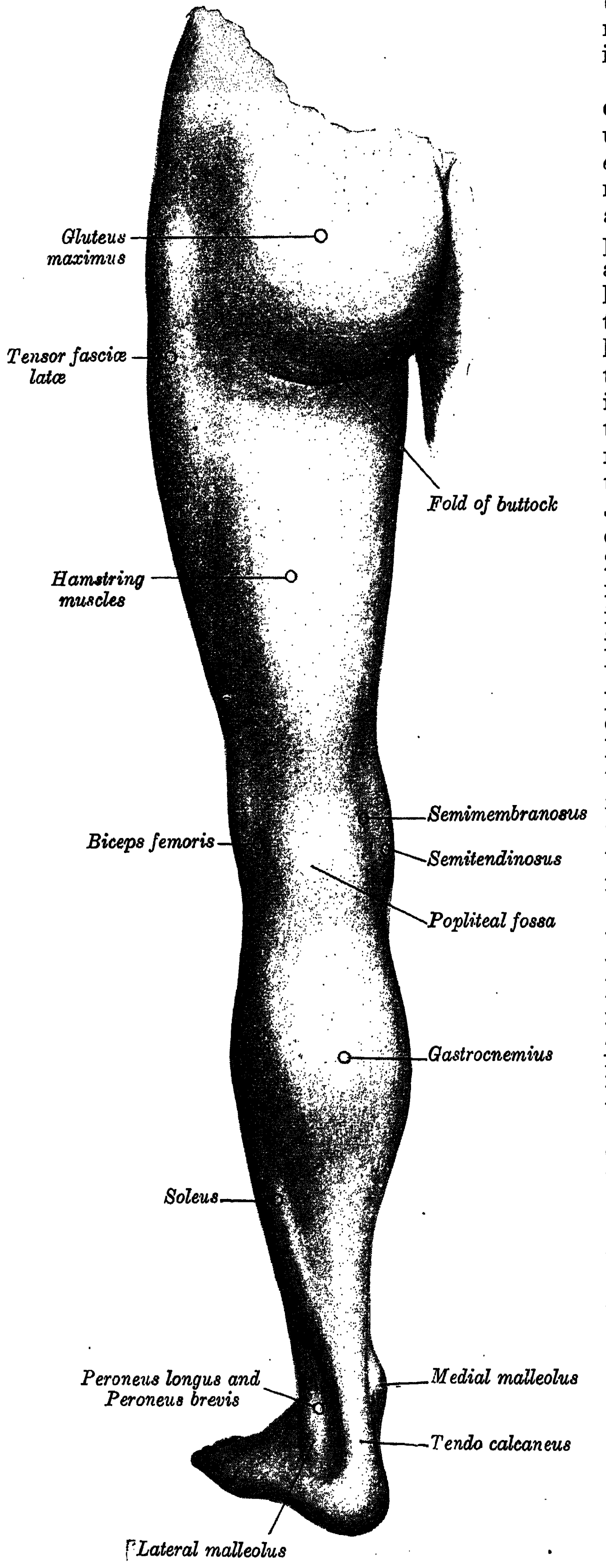
The rounded fleshy mass which occupies the upper part of the back of the thigh is formed by the *biceps femoris*, on the lateral side, and the *semitendinosus* and the *semimembranosus*, on the medial

Fig. 1303.—The back of the left lower limb, showing the surface markings for the bones, vessels, and nerves.



side. These muscles stand out boldly when the knee is flexed against resistance, and can then be traced upwards till they disappear under cover of the gluteus maximus to reach the ischial tuberosity.

Fig. 1304.—The back of the left lower limb.



Surface relations of other structures.—The upper border of the *gluteus maximus* muscle commences on the iliac crest about 3 cm. lateral to the posterior superior spine and runs downwards and laterally to the apex of the greater trochanter; its lower border corresponds to a line drawn from the ischial tuberosity, through the midpoint of the gluteal fold, to a point 9 cm. below the greater trochanter. The *sciatic nerve* (fig. 1303) enters the gluteal region 2·5 cm. lateral to the midpoint of the line joining the posterior superior iliac spine to the ischial tuberosity. It can be represented by a broad line drawn downwards and laterally from this point to cross the line joining the ischial tuberosity to the apex of the greater trochanter just medial to its mid-point. It is then continued vertically down the back of the thigh to the upper angle of the popliteal fossa, where it divides into the *medial* and *lateral popliteal nerves*, if it has not already done so at a higher level.

The *inferior gluteal artery* enters the buttock to the medial side of the point at which the sciatic nerve emerges from the pelvis. The *superior gluteal artery* emerges from the pelvis at the junction of the upper and middle thirds of a line joining the posterior superior iliac spine to the apex of the greater trochanter.

It should be observed that the line joining the posterior superior iliac spine to the ischial tuberosity

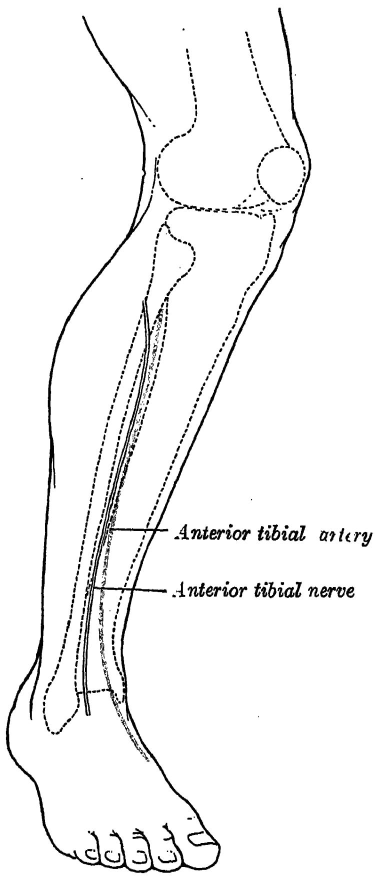
passes through both the posterior inferior iliac spine and the spine of the ischium (fig. 1303).

A line drawn from the anterior superior iliac spine to the most prominent part of the tuberosity of the ischium crosses the apex of the greater trochanter and the centre of the acetabulum ; it is frequently termed Nélaton's line. A line joining the apices of the greater trochanters should be parallel to the line joining the two anterior superior iliac spines. These lines are occasionally useful for clinical purposes.

The Leg and Ankle Regions

Surface landmarks.—The flat, anteromedial aspect of the leg conforms to the subcutaneous *medial surface of the tibia*. Above, this surface merges into the medial condyle of the tibia and below it is continuous with the visible prominence of the *medial malleolus*. The sinuous *anterior border of the tibia*, or shin, can be felt distinctly in most of its extent, but, below, it is somewhat masked by the tendon of the tibialis anterior, which lies to its lateral side. The *long saphenous vein* can often be seen as it runs upwards and backwards across the medial surface of the tibia, a little above the medial malleolus. It then ascends along the medial side of the leg to the knee, where it crosses the medial condyle of the femur.

Fig 1305.—The lateral surface of the right leg, showing the surface markings for the bones, the anterior tibial and dorsalis pedis arteries, and the anterior tibial nerve.



The *lateral malleolus of the fibula* (fig. 1305) forms a conspicuous projection on the lateral side of the ankle. It descends to a lower level than the medial malleolus and is placed on a more posterior plane. The lateral aspect of the lateral malleolus is continuous above with an elongated, triangular area of the shaft of the fibula, which is also subcutaneous. Immediately in front of the base of the lateral malleolus, the lateral part of the anterior margin of the lower end of the tibia can be made out, and the line of the *ankle joint* can be gauged from it.

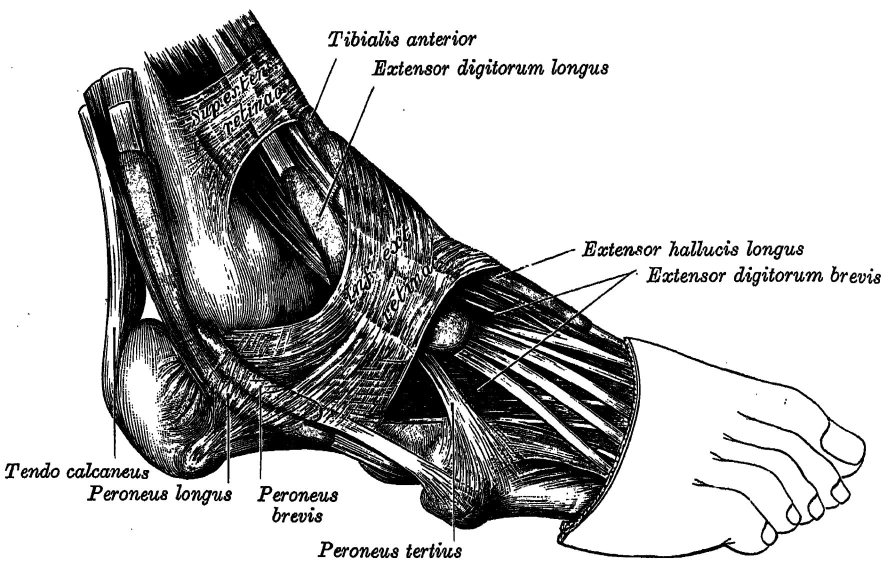
The muscles in the anterior osteofascial compartment of the leg form a gentle prominence over the upper two-thirds of its anterolateral aspect, and this prominence is accentuated when the foot is actively dorsiflexed and inverted. In the lower third of the leg, the muscles give place to their tendons. The tendon of the *tibialis anterior* can be seen just lateral to the anterior border of the tibia and traced downwards and medially across the front of the ankle to the medial side of the foot ; the other tendons cannot be examined satisfactorily above the ankle.

During active eversion and plantar flexion of the foot, the *peroneus longus* muscle (fig. 1302) can be seen as a narrow ridge on the lateral aspect of the leg. It hides the peroneus brevis, and both muscles cover the lateral aspect of the fibula, rendering its examination difficult. The tendon of the peroneus longus can be felt behind the triangular subcutaneous area of the fibula, but it disappears behind the lateral malleolus, where it is bound down by the superior peroneal retinaculum.

The bulky prominence of the calf of the leg is formed by the *gastrocnemius* and the *soleus*, both of which can be identified when the foot is plantar-flexed against resistance, or when the heel is raised from the ground, e.g. in standing on tiptoes. The medial head of the gastrocnemius descends to a lower level than the lateral head. The soleus projects from under cover of the gastrocnemius (fig. 1304), especially on the lateral side, and its fleshy belly extends to a lower level. Both muscles end below in the conspicuous *tendo calcaneus*, which can be gripped between the finger and thumb and followed down to its insertion into the posterior aspect of the calcaneum.

Immediately above the medial malleolus and close to the medial border of the tibia, the tendons of the *tibialis posterior* and *flexor digitorum longus* can

FIG. 1306.—The synovial sheaths of the tendons round the ankle. Lateral aspect. (From a preparation by J. C. B. Grant.)



be felt when the foot is actively inverted and plantar-flexed, but they are not conspicuous landmarks.

Surface relations of other structures.—The *anterior tibial artery* (fig. 1305) can be represented by a line which begins 2·5 cm. below the medial side of the head of the fibula and runs downwards and slightly medially to the midpoint between the two malleoli. Deeply placed above, the vessel is relatively superficial at the ankle, where it lies behind the tendon of the extensor hallucis longus. The *anterior tibial nerve* (deep peroneal nerve) commences on the lateral aspect of the neck of the fibula ; it is directed downwards and medially and soon comes into relationship with the anterior tibial artery, which it accompanies to the ankle. The *musculo-cutaneous nerve* (superficial peroneal nerve) also begins on the lateral aspect of the neck of the fibula ; it descends to a point on the anterior border of the peroneus longus, at the junction of the middle and lower thirds of the leg, where it pierces the deep fascia and divides into medial and lateral branches, which gradually diverge as they descend to reach the dorsum of the foot.

The *superior extensor retinaculum* (transverse crural ligament) (fig. 1306) can be represented as a band, 3 cm. deep, which passes from the anterior border of the triangular subcutaneous area of the fibula to the lower part of the anterior border of the tibia. As the tendon of the *tibialis anterior* descends behind the medial part of the ligament, it is provided with a synovial sheath which extends, both upwards and downwards, beyond the limits of the ligament.

The *posterior tibial artery* corresponds to a line drawn from the middle line on the back of the calf, at the level of the neck of the fibula, to a point midway

between the medial malleolus and the tendo calcaneus. The same line can be utilised to represent the *posterior tibial nerve.*

The *synovial sheaths* which envelop the tendons of the peroneus longus and brevis are shown in fig. 1306.

THE FOOT

Surface landmarks.—When the toes are dorsi-flexed, the *extensor digitorum brevis* forms a small elevation on the dorsum of the foot, a little in front of the lateral malleolus. At its posterior end the anterior part of the upper surface of the calcaneum can be identified, when the muscle is relaxed. When the foot is passively inverted, the upper and lateral part of the *head of the talus* can be both seen and felt ; it lies 3 cm. in front of the lower end of the tibia, and is obscured by the extensor tendons when the toes are dorsi-flexed. The tendon of the *tibialis anterior,* which stands out conspicuously on the medial side during dorsi-flexion of the ankle joint combined with inversion of the foot, can be traced downwards and medially to the *medial cuneiform bone.* When the toes are dorsi-flexed, the tendon of the *extensor hallucis longus* can be identified lateral to the tibialis anterior, and still more laterally—immediately in front of the lateral part of the lower end of the tibia—the *extensor digitorum longus* and the *peroneus tertius* tendons are crowded together as they pass through the fibrous loop of the inferior extensor retinaculum (cruciate ligament) (p. 650). After traversing the loop, the tendons diverge to their insertions. The *synovial sheaths* which envelop these tendons are shown in fig. 1306.

The dorsal venous arch forms a conspicuous feature on the dorsum of the foot, especially when it is warm, e.g. after a hot bath ; it curves, convex forwards, across the metatarsus. The long saphenous vein arises from its medial end and runs upwards and backwards in front of the medial malleolus (p. 1471), while the short saphenous vein arises from its lateral end and passes backwards below, and then upwards behind, the lateral malleolus.

The dorsal aspects of the bodies of the *metatarsal bones* can be felt more or less distinctly, but they tend to be obscured by the extensor tendons of the toes. Half-way along the lateral border of the foot, the tubercle on the base of the *fifth metatarsal bone* forms a distinct projection, which can be both seen and felt.

The flat, *lateral surface of the calcaneum* can be palpated on the lateral aspect of the heel and can be traced forwards, below the lateral malleolus, where it is hidden by the tendons of the peroneus longus and brevis. The *peroneal tubercle,* when present and pronounced, can be felt 2 cm. below the tip of the lateral malleolus ; immediately above it the peroneus brevis tendon can be traced forwards to the tubercle on the base of the fifth metatarsal bone, when the foot is actively everted and plantar-flexed.

On the medial side of the foot, the *sustentaculum tali* can be felt 2 cm. vertically below the medial malleolus ; it is partly obscured by the flexor digitorum longus tendon and the flexor retinaculum (fig. 1307). Behind and below the sustentaculum tali, the medial aspect of the calcaneum can be felt indistinctly. The *tuberosity of the navicular bone* is the most conspicuous bony landmark on the medial side and sole of the foot. Usually visible, it can always be felt 2·5 cm. in front of the sustentaculum tali. The medial cuneiform bone has already been identified, and its joint with the first metatarsal bone can be felt as a narrow groove in its upper and medial part (Pl. XII).

When the foot is placed on the ground it rests on the posterior part of the inferior surface of the calcaneum, the heads of the metatarsal bones and, to a lesser extent, on its lateral border. The *instep,* which corresponds to the medial longitudinal arch of the foot (p. 516) is elevated from the ground. The *tubercles* of the calcaneum can be examined, but they are obscured by the tough fibro-fatty pad which covers them. The heads of the metatarsal bones, also covered with a thick pad, form the ball of the foot ; at this level the foot is widest, owing to the slight splay of the metatarsal bones as they pass forwards.

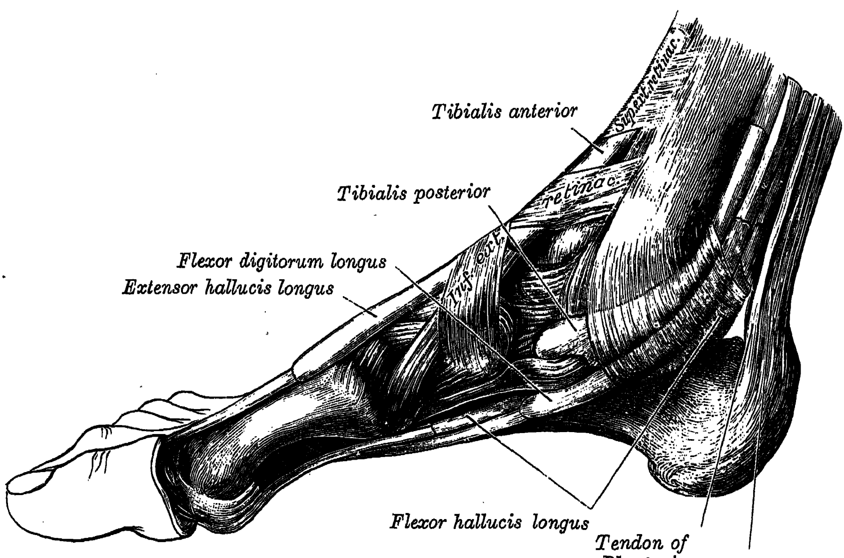
On the dorsum of the foot the skin is thin, loosely connected to the subjacent parts and containing a few hairs ; on the plantar aspect, and especially

over the heel, the epidermis is of great thickness and hairs and sebaceous glands are absent, as in the palm of the hand.

Surface relations of other structures.—The stem of the *inferior extensor retinaculum* (cruciate crural ligament) (p. 650) is attached to the anterior part of the upper surface of the calcaneum. It can be represented by a band, about 1·5 cm. wide, which passes medially on to the dorsum of the foot. On the medial side of the tendons of the extensor digitorum longus, the band divides into two diverging limbs, each 1 cm. wide. The upper limb passes to the medial malleolus; the lower passes round the medial aspect of the foot to gain the plantar aspect. The *dorsalis pedis artery* corresponds to a line drawn from the midpoint between the two malleoli to the proximal end of the first intermetatarsal space (fig. 1305).

The *calcaneocuboid joint* lies 2 cm. behind the tubercle on the base of the fifth metatarsal bone, and is practically in line with the *talonavicular joint*, the

FIG. 1307.—The synovial sheaths of the tendons round the ankle. Medial aspect. (From a preparation by J. C. B. Grant.)



position of which may be gauged from the head of the talus (p. 1473). These two joints together constitute the *transverse tarsal joint*. The *tarsometatarsal joints* lie on a line joining the tubercle of the fifth metatarsal bone to the tarsometatarsal joint of the great toe. When the latter joint cannot be felt on the medial border of the foot, its position may be indicated 2·5 cm. in front of the tuberosity of the navicular bone. The joint between the second metatarsal and the intermediate cuneiform bone lies 2 mm. to 3 mm. behind the line of the other tarsometatarsal joints (Pl. XII). The *metatarsophalangeal joints* lie 2·5 cm. behind the webs of the toes.

The *flexor retinaculum* (laciniate ligament) (fig. 1307) forms a broad band, 2·5 cm. wide, which passes downwards and backwards from the medial malleolus to the medial aspect of the heel; its lower border runs from the tip of the malleolus to the medial tubercle of the calcaneum. The *tibialis posterior tendon* lies under cover of the flexor retinaculum close to its tibial attachment and then curves forwards in the interval between the medial malleolus and the sustentaculum tali to reach the tuberosity of the navicular bone. The *flexor digitorum longus tendon* curves forwards below the tibialis posterior, lying on the medial aspect of the sustentaculum tali; from there it passes forwards and laterally to the centre of the sole of the foot, where it breaks up into tendons for the lateral four toes. The *flexor hallucis longus tendon* lies below the sustentaculum tali and, as it passes forwards to the great toe, it crosses the line of the flexor

digitorum longus opposite the interval between the sustentaculum tali and the tuberosity of the navicular bone, i.e. below the *plantar calcaneonavicular ligament*, which can be represented in this interval. The synovial sheaths which envelop these tendons are shown in fig. 1307.

The *medial plantar artery* and *nerve* commence under cover of the flexor retinaculum, midway between the medial malleolus and the prominence of the heel. From this point a line drawn forwards in the direction of the first interdigital cleft as far as the navicular bone represents, with sufficient accuracy, both the nerve and the artery. The *lateral plantar artery* and *nerve* can be represented by a line drawn from the same starting-point forwards and laterally to a point 2·5 cm. medial to the tubercle of the fifth metatarsal bone. A line drawn medially from that point, with a slight forward convexity, to the proximal end of the first intermetatarsal space represents the *plantar arch* and the *deep branch of the lateral plantar nerve*.

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THE UNIVERSITY PRESS, GLASGOW